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TEST OF THE DYNA-METRIC AIRCRAFT READINESS AND SUSTAINABILITY ASSESSMENT MODEL

(SHORT TITLE: OPTP Dyna-METRIC)

No DTIC

NOVEMBER 1984

PREPARED BY
FORCE SYSTEMS DIRECTORATE

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The test purpose was to determine the suitability of the Dyna-METRIC computer model for analyzing theater wartime aircraft fleet sustainability and parts requirements. Dyna-METRIC was (1) compared to the Overview and PARCOM Models used in the CAA Aircraft Spare Stockage Methodology Study and (2) evaluated for representing various controlled-substitution policies. Results suggested that Dyna-METRIC can (1) effectively represent a theater Army helicopter force in wartime, (2) provide comparable results to Overview and PARCOM, (3) perform fleet capability assessments under various

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controlled-substitution policies, and (4) answer a broad range of aircraft logistics questions. Dyna-METRIC is an excellent model with a high expectation of utility in detailed studies of the Army aircraft logistics system. Additional work would substantiate its applicability and further define and alleviate its limitations.

TECHINICAL PAPER
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TEST OF THE DYNA-METRIC AIRCRAFT READINESS AND SUSTAINABILITY ASSESSMENT MODEL

(SHORT TITLE: OPTP Dyna-METRIC)

NOVEMBER 1984

PREPARED BY
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CONCEPTS ANALYSIS AGENCY
CAA
UNITED STATES ARMY

TEST OF THE DYNA-METRIC AIRCRAFT READINESS AND SUSTAINABILITY ASSESSMENT MODEL (OPTP Dyna-METRIC)

STUDY
SUMMARY
CAA-TP-84-12

THE REASON FOR PERFORMING THIS WORK was to satisfy the concern resulting from the Aircraft Spare Stockage Methodology (Aircraft Spares) Study for a partial-substitution modeling capability. The Overview and PARCOM Models recommended by that study met all of the original objectives but did not allow for modeling partial substitution.

THE PRINCIPAL FINDINGS of the work reported herein are as follows:

(1) The Dyna-METRIC computer model can effectively represent a theater Army helicopter force in wartime for purposes of analyzing fleet sustainability and parts requirements.

(2) Dyna-METRIC results agreed well with those of the Overview and PARCOM Models in answering questions posed in the Aircraft Spares Study.

(3) Dyna-METRIC can represent full, no, and partial substitution of replacement parts.

(4) Requirements assessments under partial substitution cannot be performed directly with a single run. The feature could probably be added by the model developer without serious difficulty.

(5) An extended PARCOM, now available, includes the ability to represent partial substitution and eliminates the need for Overview. Although Dyna-METRIC can do most of what extended PARCOM does and has some additional valuable features, Dyna-METRIC is not recommended for aggregated theater level analysis (as in Aircraft Spares) because it is more difficult to use and interpret than PARCOM.

(6) Dyna-METRIC has unique features which are potentially valuable for higher resolution analyses than possible with PARCOM. Because testing was limited to a lower resolution problem not exercising these features, further evaluation of Dyna-METRIC is warranted.

THE MAIN ASSUMPTION was that parts fail according to flying hours only.

THE PRINCIPAL LIMITATIONS were:

(1) That treatments of partial substitution other than splitting the parts into substitutable and nonsubstitutable sets may not be addressable by Dyna-METRIC.

(2) That Dyna-METRIC was not fully tested for features relevant to expanded applications of possible interest to the Army but beyond the stated objectives of this work.

THE SCOPE OF THE WORK was to model an Army theater helicopter fleet in wartime in order to determine fleet sustainability and parts requirements based upon a postulated flying hour program. Maintenance resources were unconstrained in the analysis.

THE OBJECTIVES were to test the ability of Dyna-METRIC to represent: (1) theater level operations, (2) sparing to aircraft availability goals, and (3) partial substitution. Beyond these stated objectives, this effort also considered how Dyna-METRIC might improve Army spares analysis through (1) a detailed representation of the stochastic processes involved and (2) the modeling of more of the logistics system characteristics than were modeled in the Aircraft Spares Study.

THE BASIC APPROACH was:

(1) Duplicate the Aircraft Spares Study scenario and compare results with those from Overview and PARCOM.

(2) Evaluate partial-substitution capabilities.

(3) Examine sensitivity of results to selected key variables.

(4) Examine potential applications to more detailed studies.

THE SPONSOR was the Office of the Deputy Chief of Staff for Logistics, Department of the Army. This work was part of the Overview/PARCOM Turnkey Project (OPTP).

THIS WORK was conducted by Mr. Thomas A. Rose, Force Systems Directorate, US Army Concepts Analysis Agency.

COMMENTS AND QUESTIONS may be directed to the Director, US Army Concepts Analysis Agency, ATTN: CSCA-FS, 8120 Woodmont Avenue, Bethesda, MD 20814-2797.

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CONTENTS

CHAPTER Page

1 INTRODUCTION 1-1

Purpose 1-1
Objectives 1-1
Background 1-1
Approach 1-4
Reporting of Conclusions 1-6

2 DESCRIPTION OF THE DYNA-METRIC MODEL 2-1

General 2-1
Versions of the Model 2-2
Principal Features of the Model 2-3
Model Data Requirements 2-5

3 VERIFICATION AGAINST RESULTS OF AIRCRAFT SPARES STUDY 3-1

General 3-1
The System Modeled 3-1
Capability Assessment for Full and No Substitution . 3-4
Requirements Assessment for Full Substitution 3-6
Requirements Assessment for No Substitution 3-8

4 EXAMINATION OF PARTIAL SUBSTITUTION 4-1

General 4-1
Dyna-METRIC Partial-substitution Features 4-1
Cases Examined 4-1
Partial-substitution Capability Assessment 4-2
Partial-substitution Requirements Assessment 4-4

5 EXCURSIONS 5-1

General 5-1
Effect of Variations in Operational Availability Targets 5-1
Effect of Variations in Confidence Level Goals 5-2
Effect of Different Controlled-Substitution Policies 5-2

6 STRENGTHS AND SHORTCOMINGS OF DYNA-METRIC 6-1

Introduction 6-1
Features in Common with PARCOM 6-1
Dyna-METRIC Strengths 6-2
Dyna-METRIC Shortcomings 6-5

CHAPTER Page

7 CONCLUSIONS 7-1

Aircraft Spares Theater Comparison 7-1
Partial Substitution 7-1
Dyna-METRIC versus Overview and PARCOM 7-1
Recommendations 7-1

APPENDIX

A Acknowledgement A-1
B Differences Between Dyna-METRIC Versions 3.04 and 4.3 .... B-1
C Model Installation Experience C-1
D References D-1

GLOSSARY Glossary-1

STUDY SUMMARY (tear-out copies)

FIGURES

FIGURE

1-1 Test Methodology 1-5

3-1 Aircraft Spares Study Parts Flow Diagram 3-2
3-2 Comparison of Capability Assessments; Full Substitution, Dyna-METRIC and PARCOM Models 3-5
3-3 Comparison of Capability Assessments; No Substitution, Dyna-METRIC and PARCOM Models 3-5
3-4 Comparison of Aircraft Spares Cost Estimates to Achieve Wartime Flying Hour Programs; Full Substitution, Dyna-METRIC and PARCOM Models 3-7
3-5 Comparison of Aircraft Spares Cost Estimates to Achieve Wartime Flying Hour Program; No Substitution, Dyna-METRIC and PARCOM Models 3-9

4-1 Substitution Policy Effect on Capability Assessments, Dyna-METRIC Model 4-2
4-2 Comparison of Capability Assessments; Partial Substitution, Dyna-METRIC and PARCOM Models 4-4

FIGURE Page

5-1 Cost Estimates to Meet Various Availability Goals; No Substitution, Dyna-METRIC Model, 50 Percent Confidence 5-1
5-2 Cost Estimates to Increase Confidence Level; Full Substitution, Dyna-METRIC Model, 50 Percent Availability 5-2
5-3 Capability Assessments of Current Inventory; Full, Partial, and No Substitution, Dyna-METRIC Model 5-3

TABLES

TABLE

1-1 Demonstration Question Set for Aircraft Spares Study 1-3

3-1 Comparison of Aircraft Spares Required; Full Substitution, Dyna-METRIC and PARCOM Models 3-8
3-2 Comparison of Aircraft Spares Required; No Substitution, Dyna-METRIC and PARCOM Models 3-10

6-1 Dyna-METRIC Strengths 6-2
6-2 Dyna-METRIC Shortcomings 6-6

TEST OF THE DYNA-METRIC AIRCRAFT READINESS AND SUSTAINABILITY ASSESSMENT MODEL

(Short title: OPTP Dyna-METRIC)

CHAPTER 1

INTRODUCTION

1-1. PURPOSE. The purpose of this effort was to determine the suitability of the Dyna-METRIC (Dynamic Multi-Echelon Technique for Recoverable Item Control) computer model for analyzing theater wartime aircraft fleet sustainability and parts requirements. This work was a part of the Overview/PARCOM Turnkey Project (OPTP) performed for the Department of the Army, Office of the Deputy Chief of Staff for Logistics (DA, ODCSLOG).

1-2. OBJECTIVES. The stated objectives were to test the ability of Dyna-METRIC to represent (a) theater level operations, (b) sparing to aircraft availability goals, and (c) partial substitution of spares. Demonstrating partial substitution was the principal objective. The theater level comparison with the results of the Aircraft Spare Stockage Methodology (Aircraft Spares) Study[1] was an essential validation step. Determining spare requirements (sparing) based on aircraft availability goals is inherent to Dyna-METRIC's operation (hence, not treated as a separate objective). Beyond these objectives, this effort also considered how Dyna-METRIC might provide a means for improving on current Army budget estimation methodology through (a) a detailed representation of the stochastic processes involved and (b) the modeling of more of the logistics system characteristics than were modeled in Aircraft Spares.

1-3. BACKGROUND

a. Definitions

(1) Substitution Policies. Substitution, as used in this report, refers to the practice of removing a part from one unflyable aircraft and placing it on another unflyable aircraft so as to make the latter aircraft flyable. The report distinguishes between three types of substitution policies: no, full, and partial substitution. A no-substitution policy is one in which substitution is not allowed. A full-substitution policy is one in which all parts can be substituted. A partial-substitution policy is one in which certain parts can be substituted and others cannot, based on specific selection criteria. A range of specific partial-substitution policies, corresponding to different sets of selection criteria, is possible.

(2) Capability and Requirements Assessments. To varying degrees, the three models compared in this work (Dyna-METRIC, Overview,[1,2,3] and PARCOM[1]) may be executed in either or both of two fundamental modes: capability assessment and requirements assessment. In a capability assessment, the models determine how well the aircraft fleet can meet a postulated flying hour program or achieve specified availability goals with a specified initial stockage of parts. In a requirements assessment, the models determine what additional parts should be purchased to fully meet the flying hour or availability goals.

(3) **Basic and Extended PARCOM.** Basic PARCOM is the version of the Parts Requirements and Cost Model[1] developed in the Aircraft Spares Study to assess aircraft fleet performance and parts requirements. It plays full and no substitution, but not partial substitution, and introduces all theater-deployed spare parts at the beginning of the war rather than over time. Concurrently with the testing of Dyna-METRIC in OPTP, another version of PARCOM, extended PARCOM,[4] was developed to include partial substitution and deployment of parts over time. The latter modification will enable extended PARCOM to completely replace the Overview Model in spare parts analysis. For this test, theater level comparisons of Dyna-METRIC were made originally with basic PARCOM (and Overview) and later with extended PARCOM. When PARCOM results are shown in this report, they are for extended PARCOM (they do not differ substantially from those of basic PARCOM). Comparisons of Dyna-METRIC and PARCOM results for partial substitution, of course, can only be done with extended PARCOM.

b. Aircraft Spares Study

(1) **Purpose.** The Aircraft Spare Stockage Methodology (Aircraft Spares) Study, completed in April 1984 for ODCSLOG, was conducted to develop candidate methodologies for the purpose of forecasting wartime aircraft spare parts requirements. Primarily, the study was to provide the Army with a tool for quick reaction, gross estimation of wartime spare parts requirements and costs as they relate to flying hours and availability. The tool was to be able to answer questions, such as those in Table 1-1, of importance to headquarters-level decisionmakers for the planning and budgeting process.

(2) **Recommendations.** The Aircraft Spares Study recommended that two simulation models, Overview and PARCOM, be used for the above-stated purpose. The Overview Model was developed by Synergy, Inc. for the Air Force and, later, was modified to assess aircraft fleet performance and parts requirements for the Army. It could only do so, however, in a full-substitution mode and for unlimited budgets. PARCOM, defined earlier, was developed during the study to meet these perceived Overview shortcomings. Aircraft Spares also examined, but did not test, Dyna-METRIC, which is a much more complex and detailed model. Based on that examination, Dyna-METRIC appeared capable of answering a wider range of questions than Overview and PARCOM and, in particular, of analyzing sustainability under a partial-substitution policy. Since Overview and PARCOM could not model partial substitution at that time, the US Army Concepts Analysis Agency (CAA) was asked to test Dyna-METRIC.

Table 1-1. Demonstration Question Set for Aircraft Spares Study

---

Typical flying hour based questions

- **Assessment of current parts inventory**
  - For how many consecutive days could the wartime flying hour program (FHP) be fully met?
  - What fraction of the cumulative FHP objective could be achieved?
  - What would the current procurement costs of the inventory be?
- **Requirements determinations**
  - What is the minimum cost mix of parts required to achieve 100 percent of the cumulative FHP?
    - What is the cost of those parts?
    - What parts dominate the process? How?
    - What is the fractional increase in the cost of parts to achieve the cumulative FHP?
  - For a given budget (say $10M) and FHP, what parts should be bought?
    - to maximize sustained performance?
    - to maximize cumulative flying hours?
- **Marginal performance.** What is the marginal improvement in cumulative FHP as expenditures increase?

Typical aircraft availability questions

- **Marginal performance.** What is the marginal improvement in average availability as expenditures increase?
- **Daily availability goal.** What is the cost of meeting an additional objective of at least 85 (or some other) percent availability every day of the FHP?
- **Average availability goal.** What is the cost of meeting 85 (or some other) percent average availability while meeting the FHP?

---

(3) Scenario. The basic scenario for the Aircraft Spares Study was the first 120 days of a postulated war in Europe. The AH-1S helicopter fleet and spares inventory was used to develop and test the methodology.

(4) Model Methodology. Overview and PARCOM focus on the supply aspects of the parts supply and repair system. Time delays associated with repair of parts are represented; however, those delays are constant (represent the average) for each part independent of maintenance workload and availability of test equipment. One depot is represented in the continental United States (CONUS). All aircraft units in theater are aggregated into a single entity, as if all aircraft operate from a single base. Collocated with the aircraft are an aggregated stockage of parts and an aggregated repair capability corresponding to all theater aviation unit maintenance (AVUM) and aviation intermediate maintenance (AVIM) resources. Some aircraft units, AVUMs and AVIMs, are in place in theater prior to the war. Others are deployed in a time-phased sequence during the war. As these resources arrive in theater, their assets are added to those of the aggregated retail storage and repair facility. The major simplifications from real-world conditions which result from using this methodology are:

- All aircraft can contribute to flying a combined theater flying hour program.
- Part substitution, when allowed, is across all aircraft in the theater fleet.
- No distinction is made between repair times of different AVUMs and AVIMs. Shipping delays between AVUMs and AVIMS are not directly represented.

1-4. APPROACH

a. General. Figure 1-1 shows the approach used to meet the objectives of the Dyna-METRIC test. Steps 1, 2, and 3 address the first objective: to determine if Dyna-METRIC can represent theater wartime aircraft logistics functions as well as (or better than) Overview and PARCOM. Steps 4 and 5 address the last objective: to determine if Dyna-METRIC can represent a partial-substitution part replacement policy. Step 6 was the reporting of the results of steps 1 through 5.

b. Steps

(1) Defining the Input. The first objective required that Dyna-METRIC be applied to solving the same theater level problem as in the Aircraft Spares Study. Thus, all information describing the scenario and parts was drawn from that study. Actual Overview and PARCOM results from that study would then be used in comparisons with Dyna-METRIC results in step 3 of the test methodology.

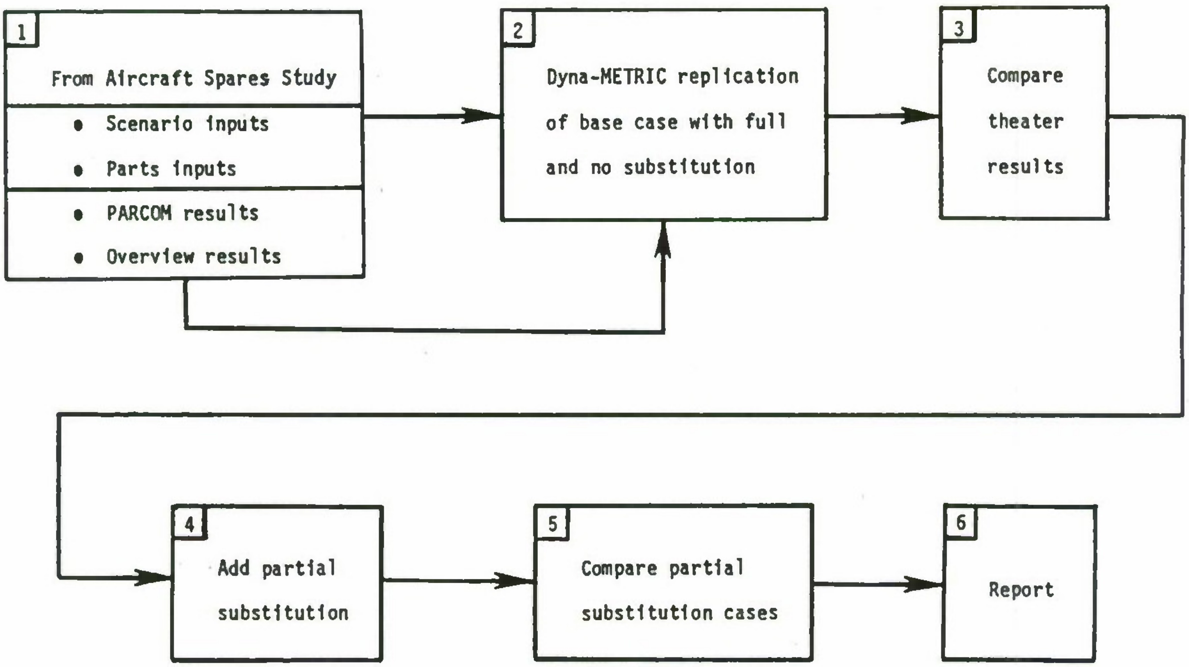
1
From Aircraft Spares Study
• Scenario inputs
• Parts inputs
• PARCOM results
• Overview results
2
Dyna-METRIC replication of base case with full and no substitution
3
Compare theater results
4
Add partial substitution
5
Compare partial substitution cases
6
Report

Figure 1-1. Test Methodology

(2) **Theater Level Runs.** Dyna-METRIC was executed in a manner to match as closely as possible the theater level conditions under which Overview and PARCOM were used during the Aircraft Spares Study. This process involved computations under both a full-substitution policy and a no-substitution policy, as in that study.

(3) **Comparing Theater Level Results.** Dyna-METRIC results were compared to results obtained with Overview and PARCOM in the Aircraft Spares Study. No empirical information exists which could be used to verify the overall results of the models. In the Aircraft Spares Study, numerous manual calculations were made to validate specific computations performed by Overview and PARCOM. Those checks, along with a detailed step-by-step examination of the logic of the models, yielded a high degree of confidence in the operational validity of the models. Dyna-METRIC results were verified through comparison to the results of Overview and PARCOM and by numerous additional manual calculations.

(4) Partial Substitution Runs. After the successful completion of the first objective, Dyna-METRIC was applied to modeling partial substitution. Except for changes in substitution policy, no changes were made to the scenario modeled thus far. Several cases, using different criteria for determining which parts were deemed substitutable, were run.

(5) Comparing Partial Substitution Results. Dyna-METRIC results under partial-substitution policies were contrasted against Dyna-METRIC results under full- and no-substitution policies. A contrast against the partial-substitution results obtained from extended PARCOM was also made.

(6) Reporting Test Results. The results of this test are reported in subsequent chapters. Chapter 2 contains a general description of the Dyna-METRIC Model, including data requirements for the cases run to meet the test objectives. Chapters 3 and 4 describe the results from accomplishing the test objectives.

c. Additional Work

(1) Excursions. During this test, it became apparent to the author that Dyna-METRIC was an effective and powerful model with potential application beyond the scope of this work. It was therefore decided to examine, within the time constraints of the test, certain additional model features not directly relevant to the test, to gain insights into the model's potential applications. In this connection, three excursions felt to be of particular interest were performed. These excursions analyze the effects of variations in (1) operational availability targets, (2) confidence level goals, and (3) substitution policies, and are described in Chapter 5.

(2) Strengths and Shortcomings. Chapter 6 is a summary of insights gained as to the strengths and shortcomings of the Dyna-METRIC Model. As many model features as possible were considered. Thus, Chapter 6 is a summary of Dyna-METRIC's applicability, not only to problems relevant to the test, but also to a broader scope of potential applications.

1-5. REPORTING OF CONCLUSIONS. Chapter 7 summarizes the results of all of the work reported herein and includes recommendations as to the future use of the models. The conclusions are based on both the testing done to meet the stated objectives and the additional work which was considered justified.

CHAPTER 2

DESCRIPTION OF THE DYNA-METRIC MODEL

2-1. GENERAL

a. Genesis. Dyna-METRIC was developed by the Rand Corporation, in its continuing support of the Air Force, as an improvement to METRIC (Multi-Echelon Technique for Recoverable Item Control),[5] an earlier model used to compute optimal inventory requirements for steady-state activity levels. The steady-state constraints of METRIC are comparable to those of the SESAME Model,[6] which is used by the Army for initial provisioning computations, and which was one of the candidate models examined in the Aircraft Spares Study. Dyna-METRIC (as suggested by its name) models certain dynamic characteristics of wartime (variable flying intensity, variable attrition, and phased deployment of aircraft) and certain maintenance and supply functions (of lesser interest to this task).

b. Attributes. The following excerpt from a Rand Corporation report[7] summarizes the key attributes of the Dyna-METRIC computer model:

> "Dyna-METRIC is an analytic model that uses mathematical equations to forecast how logistics support processes would affect flying units' capability in a dynamic wartime environment. Specifically, it forecasts the quantity of each aircraft component in repair and resupply throughout a wartime scenario, based on the component's unique interactions with the developing operational demands. It also combines these quantities probabilistically to estimate how all the aircraft components jointly might affect aircraft availability and combat sorties throughout the scenario. Because the model is analytic, it can (optionally) identify those problem parts that most limit aircraft availability, or it can suggest a cost-effective stock purchase to improve aircraft availability."

c. Limitations. The Rand report further identifies the model's perceived limitations as:

> "1. Repair procedures and productivity are unconstrained and stationary except when repair capacities are explicitly stated.
>
> 2. Forecast sortie rates do not directly reflect flight-line resources and the daily employment plan.
>
> 3. Component failure rates vary only with flying intensity.

4. Aircraft within each base are assumed to be nearly interchangeable.

5. Repair decisions and actions occur only when testing is complete.

6. Component failure rates are not adjusted to reflect previous fully mission capable (FMC) sorties accomplished.

7. All echelons' component repair processes are identical."

d. Language. Dyna-METRIC is written exclusively in FORTRAN. With rare exceptions (Appendix C, paragraph C-5), it conforms to ANSI FORTRAN 77 (full language)[8] and, as such, is highly transportable to any computer which provides a compiler certified for FORTRAN 77 for the full language (as opposed to the ANSI FORTRAN 77 subset language[8]).

e. Availability and Documentation. Dyna-METRIC is available in a production version, employed by most users, and a more capable developmental version, which CAA tested (certain new features were necessary for this test). The basic functioning of Dyna-METRIC is well documented.[7,9] Additional documents explain how to operate the model, and two of these[10,11] were used for the work described in this report. Various reports on applications of the model also exist, and two of these[12,13] were reviewed as well. As it continues to enhance and refine the model, Rand periodically issues updated documentation and source code to the community of users.

f. Users. Currently, the model is used actively by Rand and several USAF activities, including the Air Logistics Center, the Air Force Logistics Command, the Tactical Air Command, and the Air Force Institute of Technology. The remainder of this chapter describes Dyna-METRIC in more detail, including data requirements.

2-2. VERSIONS OF THE MODEL

a. What They Are. Dyna-METRIC is maintained and distributed by Rand in two principal forms: Version 3, considered a production version, and Version 4, a developmental version. Periodically corrections, refinements, or enhancements are released. Also, periodically, updated documentation for each version is produced and disseminated. Rand maintains Versions 3 and 4 separately primarily because it does not want to release a substantially different form of the code to production users until the code has been thoroughly exercised and becomes relatively stable (not undergoing significant changes).

b. Version 3. Version 3 has been used by the USAF community for production applications for several years. Version 3 is reported to be fairly stable, well debugged, and reliable. The most recent release is 3.04, dated June 1984.

c. Version 4

(1) Version 4, Release 4.3, was used for this work because certain of the additional features (listed in Appendix B) were necessary for this test. Release 4.4 was disseminated in mid-August 1984, but time constraints precluded exercising it. The distribution letter for Release 4.4 stated the following:

> "This program is a relatively modest revision of the Version 4.3 model, primarily to incorporate estimates of wartime depot workload, a revised problem parts list (including subcomponents and a simplified graphical display of components' effects on aircraft availability), and time-phased stock deployment. Some cosmetic changes have also been incorporated (primarily a reformatted echo of base stock and pipelines)."

(2) Version 4 has been distributed only to select users whose resources and applications are such that they are in a position to be able to identify and respond to faulty or questionable operation of the model. During the exercising of Release 4.3, difficulty was indeed encountered several times, as explained in Appendix C.

2-3. PRINCIPAL FEATURES OF THE MODEL

a. General. Dyna-METRIC models the essential features of a three-echelon parts distribution and repair system. Although designed to represent USAF functions, Dyna-METRIC also is suited to representing the Army aircraft logistics system. The model emphasizes parts availability by computing flying hour based failures, maintaining serviceable stock levels at each echelon, and tracking the flow of unserviceables through predictable repair processes, condemnations, and shipments between repair facilities. Less emphasis is placed on modeling repair resource constraints, although limited repair capacities can be explicitly represented through a slightly cumbersome procedure.

b. Nature of Computation. The following excerpt from Dyna-METRIC documentation[7] describes the essence of the computations performed by the model:

(1) "The central computation in the model is that of the expected number of components being processed by each function and echelon. Dyna-METRIC portrays component support processes as a network of pipelines through which aircraft components flow as they are repaired or replaced throughout a single theater. Each pipeline segment is characterized by a delay time that arriving components must spend in the pipeline before exiting the segment. Some delay times (e.g., local repair times) vary from component to component; others (e.g., intratheater transportation times) depend on the base being assessed. The expected number of components in each pipeline segment depends on the rate at which demands occur and the time components spend in each segment."

(2) "The sum of all pipeline segments is the key parameter for a probability distribution that specifies the probability that some number of components other than the expected number may exist in the pipeline network. The model expands each component's expected pipeline size into a complete probability distribution for the number of components currently undergoing repair and on order, so the probability distributions for all components can be combined to estimate aircraft availability and sorties."

(3) "The probability distributions are also important when the model computes requirements and identifies problem parts. When computing spares requirements, the program adds spare assets that will probably increase the number of available aircraft at minimal cost. When identifying problem parts, the model sequentially selects components based on the extent to which they will probably limit fully mission-capable (FMC) aircraft."

c. **Capability and Requirements Assessments.** Dyna-METRIC functions in the two basic assessment modes defined in Chapter 1:

(1) **Capability Assessment.** In the capability assessment mode, the model determines fleet performance for a given stockage of parts. Performance reports for each requested reporting period include fleet availability, NMCS (not mission capable due to supply) level, and achieved flying hours.

(2) **Requirements Assessment.** In the requirements assessment mode, the model determines how many additional parts must be bought to meet the requested flying hour program and a stated fleet operational availability target. Requirements determinations can be made for constrained or unconstrained dollar limits, and, for both, the incremental achieved sustainability is reported.

d. Dynamic Wartime Features

(1) The model allows for the specification of variable attrition, variable requested flying hours, and variable aircraft deployment levels.

(2) When repair facilities are discretely modeled, phased deployment of parts and repair resources can be represented.

(3) Temporary cutoff of transportation routes can be specified.

(4) Up to five different mission types can be specified, with different sets of parts designated as essential for each.

e. Probabilistic Features

(1) Repair and transportation times can be treated as either fixed or randomized.

(2) Shortages of parts are randomly distributed across on-hand aircraft.

(3) The occurrence of failures is computed probabilistically. Pipeline sizes are distributed probabilistically since they depend on variations in repair times and occurrences of failures.

(4) Based on the probabilistic nature of the model computations, confidence levels can be associated with performance statistics and requirements availability targets.

f. Level of Detail

(1) Three echelons are allowed: depot, CIRF (centralized intermediate repair facility) (can be used to represent AVIMs), and base (can be used to represent aircraft units and AVUMs).

(2) Parts can be purchased for stockage at each echelon.

(3) Within each echelon, AVIMs, aircraft units, and AVUMs can be discretely represented or grouped to any degree desired.

(4) A multiple indenture part structure, where parts are categorized as line replaceable units (LRUs), shop replacement units (SRUs), and sub-SRUs, is permitted.

g. Repair Resources

(1) A capability exists for specifying certain repair resources (e.g., test equipment, test teams, and repair personnel) as essential for repair of each part. Parts compete for limited resources, resulting in additional repair delays when essential resources are overloaded.

(2) Depot wartime repair throughput for each part can be further represented by specification of a factor which limits how many of the part can be repaired per time period. This factor can be specified explicitly or as a function of peacetime repair throughput, as computed by the model for a peacetime period prior to war.

h. Substitution

(1) Various capabilities exist for computations based on full-, partial-, and no-substitution replacement policies.

(2) When substitution is allowed, individual parts are specified by the user as being or not being candidates for substitution.

(3) Substitution, when allowed, is limited to within a base for LRUs and within a base, CIRF, or depot for SRUs and sub-SRUs.

2-4. MODEL DATA REQUIREMENTS

a. General. The data required by Dyna-METRIC for the cases run for this test essentially constitute the minimum required data for any Dyna-METRIC application. This data is identical in content, although different in format, to that required by the Overview and PARCOM Models. Additional data would be needed if certain additional Dyna-METRIC features were to be exercised (see paragraph 2-4d). The data requirements for this test are described below.

b. Scenario Data

(1) **Flying Hours** - the forecast required flying hours for each type of aircraft simulated, by day or group of days (if constant over the group of days).

(2) **Attrition** - the forecast attrition for each type of aircraft simulated, specified as either a daily quantity of aircraft lost or as a daily rate per mission.

(3) **Force Structure** - the planned force structure giving, for each aircraft type, the quantity of aircraft per company, the supporting AVIM, and the deployment dates.

(4) **Transportation Times** - the average transportation times for each route modeled.

c. Parts Data. There will be a set of values for these data elements for each part.

(1) **NSN** - national stock number or some other unique 15-digit (or less) numerical identifier.

(2) **Unit Cost** - estimated current unit purchase cost.

(3) **Administrative Lead Time** - the time delay between the decision to buy and the signing of a purchase contract.

(4) **Production Lead Time** - the time delay between the signing of a purchase contract and delivery.

(5) **Retail Repair Time** - the mean time required at the retail level (AVIM and AVUM) to repair the specified part. This is turnaround time--the period from when the part arrives at the repair facility to when it has been repaired and is ready to be shipped. It includes actual repair time, unpacking/packing time, time waiting for parts, time waiting for repair, coffee breaks, etc.

(6) **Depot Repair Time** - the mean time required at the depot to repair the specified part. This is total turnaround time as described in (5), above.

(7) **Order and Ship Time** - the mean time from issuing a requisition at the retail level until the part is delivered to the retail level.

(8) **Failure Rate** - the number of removals per flying hour.

(9) **Depot Repair Limit** - the maximum number of this part that can be repaired at the depot each day during wartime.

(10) **Retail NRTS Rate** - the percentage of times this part is not repairable at this station, i.e., sent from the retail level (AVIM and AVUM) to the depot for repair.

(11) **Retail Condemnation Percentage** - the percentage of times this part is judged not repairable and is discarded at the retail level.

(12) **Depot Condemnation Percentage** - the percentage of times this part is judged not repairable and is discarded at the depot level.

(13) **Serviceable Wholesale Inventory** - the quantity of these parts in stock and serviceable at the depot level. Due-ins at retail can be aggregated and included with the serviceable wholesale inventory or can be phased in separately by treating them as deployed retail stocks. Other war reserve materiel stocks stored at depot would be included here.

(14) **Unserviceable Wholesale Inventory** - the initial quantity of this part in unserviceable condition at the depot level.

(15) **Serviceable Retail Inventory** - the quantity of these parts stocked in the authorized stockage list (ASL) or prescribed load list (PLL) of each AVIM and AVUM being simulated.

(16) **Prepositioned War Reserves** - the quantity of this part stocked in theater as prepositioned war reserves.

(17) **Quantity per Aircraft** - the quantity of this part used on each applicable aircraft.

d. **Additional Data Requirements.** Additional data would be needed for certain Dyna-METRIC features which could be used for more complex applications than those tested here. For example, if aircraft units, AVUMs, and AVIMs were represented as discrete entities rather than aggregated, then the following additional data would be needed:

(1) Flying hour programs for each unit, if different.

(2) Transportation times for all new routes.

(3) Repair times for each part, for each AVUM and AVIM.

(4) NRTS rates for each part, for each AVUM and AVIM.

(5) Condemnation rates for each part, for each AVUM and AVIM.

(6) Stockage levels for each part, for each AVUM and AVIM.

For each new detail represented, supporting data is required. In Chapter 6, along with the discussion of each Dyna-METRIC strength, relevant data concerns are addressed for the features of potential application.

CHAPTER 3

VERIFICATION AGAINST RESULTS OF AIRCRAFT SPARES STUDY

3-1. GENERAL

a. Purpose. This chapter describes the validation testing performed to determine if Dyna-METRIC can represent theater wartime aircraft logistics functions as well as (or better than) Overview and PARCOM. To accomplish this validation, Dyna-METRIC full- and no-substitution results were compared with those obtained with Overview and PARCOM during validation of those models in the Aircraft Spares Study. Numerous manual calculations were also made to check specific computations performed by Dyna-METRIC. These latter checks revealed no irregularities and are not reported here. After the validation, Dyna-METRIC was tested to meet the principal objective of representing partial substitution, as described in Chapter 4.

b. Scenario. The Dyna-METRIC test matched as closely as possible the scenario modeled by Overview and PARCOM in the Aircraft Spares Study. The scenario was a representative deployment in Europe of AH-1S aircraft and their associated AVUMs and AVIMs. This deployment involved having part of the fleet in place on day 1 of the war and the majority of the fleet phased in over the following 60 days. Thus, the fleet size varies substantially throughout the wartime period simulated. Postulated variable attrition rates were used, further adding to the dynamic nature of the number of on-hand aircraft. The postulated fleet flying hour program also varied with time. It generally increased as the war progressed, tracking, to a large degree, the sum of aircraft deployments. Any mission-capable aircraft was limited to a maximum number of flying hours per day to reflect the inability to fly under certain conditions (e.g., nighttime) and the turnaround time required for refueling, rearming, and inspections. The manner in which Dyna-METRIC modeled the essential features of the aircraft logistics system is described in paragraph 3-2.

c. Runs Performed. The results reported in this chapter represent four distinct cases. The first two, reported in paragraph 3-3, are capability assessments under both full-substitution and no-substitution part replacement policies. These cases determined how well the fleet could perform with a representative current stockage of parts. The last two cases, reported in paragraphs 3-4 and 3-5, respectively, are requirements assessments under full-substitution and no-substitution part replacement policies. These cases determined what additional stockage of parts was needed to allow the fleet to fully meet postulated flying hour and availability goals.

3-2. THE SYSTEM MODELED

a. Figure 3-1 shows how parts flow through the logistics system as represented in the models of the Aircraft Spares Study and as modeled by Dyna-METRIC for this test. Dyna-METRIC differs from Overview and PARCOM in that it can represent more complex structures than that shown in Figure 3-1. Where Dyna-METRIC allows more detail, attempts were made to duplicate

3-1. Where Dyna-METRIC allows more detail, attempts were made to duplicate the system shown by turning off switches or otherwise not using the features, or by varying input parameters to emulate the simpler structure. In Figure 3-1, the blocks represent locations where parts may reside. Parts move from block to block as indicated by the interconnecting lines and arrows. Movement of parts is essentially instantaneous, except where a line contains a circle and the letters DT (delay time). A path containing a delay time can be thought of as a pipeline. The aircraft fleet block and the two AVUM/AVIM blocks represent theater assets, while the two depot blocks and the industry block represent assets in CONUS.

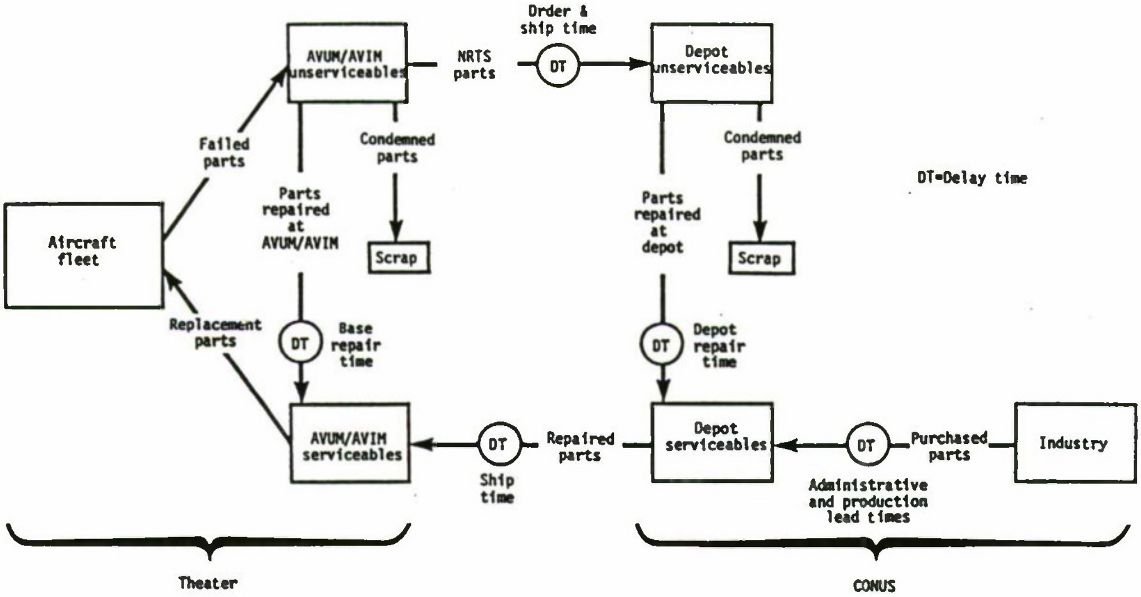
Order & ship time
AVUM/AVIM unserviceables
NRTS parts
DT
Depot unserviceables
Failed parts
Condemned parts
Parts repaired at AVUM/AVIM
Scrap
Condemned parts
DT=Delay time
Aircraft fleet
Parts repaired at depot
Scrap
Replacement parts
DT
Base repair time
DT
Depot repair time
AVUM/AVIM serviceables
DT
Repaired parts
Depot serviceables
DT
Purchased parts
Industry
Ship time
Administrative and production lead times
Theater
CONUS

Figure 3-1. Aircraft Spares Study Parts Flow Diagram

b. At the start of the simulation, serviceable parts exist on aircraft predeployed in theater, in the ASLs for AVIMs, in PLLs for AVUMs, in depot inventory, and in prepositioned war reserves. At the war's start, the latter are added into the aggregated AVUM/AVIM serviceables inventory. Overview and PARCOM allow the manual specification of unserviceables at AVUM/AVIM at the war's start. Dyna-METRIC allows one optionally to generate this by modeling a lead-in period of peacetime. Overview and PARCOM allow the specification of initial depot unserviceables. In past with PARCOM and Dyna-METRIC, depot unserviceables have simply been added to depot serviceables, with no effect on the results when compared with Overview. (Again, Dyna-METRIC optionally allows for initial wartime unserviceables at depot through a peacetime lead-in period.)

c. As the simulation progresses, parts fail at a specified rate, solely dependent on accrued fleet flying hours. As shown in Figure 3-1, failed parts are removed and sent to the aggregated AVUM/AVIM. If a serviceable replacement exists in AVUM/AVIM stocks, it is immediately installed. If not, a shortage exists, and the aircraft may or may not be NMCS (not mission capable due to supply), depending on the part substitution policy in effect and the status of other parts.

d. Of the failed parts arriving at AVUM/AVIM, various fractions are passed on to depot for repair, are condemned, or are placed in repair at AVUM/AVIM according to specified values, for each part, for NRTS (not reparable this station) and condemnation rates. NRTS parts are delayed by a specified order and ship time before arriving at depot. Condemned parts are condemned instantaneously. Parts in repair at AVUM/AVIM are available as AVUM/AVIM serviceable stocks after a repair time specified for each part. Whenever a part is condemned or shipped to depot for repair, a replacement is ordered from depot.

e. A fraction of the parts arriving at depot from AVUM/AVIM is condemned according to a specified depot condemnation rate for each part. The remaining fraction is placed in repair at depot and is available as depot serviceable stock after a delay time specified for each part. Depot serviceables are available to the AVUM/AVIM after a specified shipping time delay.

f. Parts flow from the industrial base to the depot, delayed by the sum of an administrative lead time and a production lead time specified for each part. In practice, however, this has not affected computations, since this delay time for all parts is in excess of the simulated game time.

g. For this evaluation, in order to match the other models, some major Dyna-METRIC features were not used. No indentured parts (subassemblies and components) were specified; the repair times for indentured parts were included in those of the associated major assemblies. Only two of three allowed echelons were modeled. AVIMs and AVUMs were aggregated into a single echelon. Discrete AVIMs and AVUMs were not specified. No repair resource constraints were specified.

h. A major difference with Dyna-METRIC (compared to Overview and PARCOM) is that it treats the delay times and the likelihood of failures probabilistically. The data entered for these parameters for all the models are expected values. In Overview and PARCOM, parts fail and are processed solely according to those values. In Dyna-METRIC, failures and delay times are distributed according to a Poisson or other distribution based on a user-specified variance-to-mean ratio.

i. The following adjustments to Dyna-METRIC input values were made as the evaluation progressed, to obtain better agreement with the other models.

(1) Transportation times were selected as fixed, though Dyna-METRIC allows for their probabilistic representation.

(2) The depot-to-AVUM/AVIM order and ship time was reduced to zero, and the AVUM/AVIM-to-depot ship time was increased to keep the sum constant. This kept the round trip delay for parts failed in theater the same, but portrayed the initial depot stock as predeployed to theater (in order to correspond to PARCOM representation).

(3) Probability and confidence level input values, which must be specified with Dyna-METRIC, were adjusted to approximate the expected value operation of Overview and PARCOM.

3-3. CAPABILITY ASSESSMENT FOR FULL AND NO SUBSTITUTION

a. Results - Presentation. Figures 3-2 and 3-3 compare the results of Dyna-METRIC and PARCOM for the full-substitution policy and the no-substitution policy, respectively. The line labeled "Required" represents the fleet flying hours requested (the goal). The other two lines in each figure represent the flying hours the fleet was able to fly as computed by PARCOM (labeled "Achieved PARCOM"), and Dyna-METRIC (labeled "Achieved Dyna-METRIC)." Overview full-substitution results, not shown in Figure 3-2, are essentially identical to those for PARCOM. No-substitution computations cannot be obtained with Overview.

b. Results - Discussion

(1) Sustainability. The most significant features on Figures 3-2 and 3-3 are the points at which the models predict that the fleet can no longer fully meet the flying hour program. PARCOM and Dyna-METRIC agreement is excellent. For full substitution, PARCOM determined the falloff to begin at day 72, compared to day 70 for Dyna-METRIC. For no substitution, PARCOM indicated day 39, compared to day 40 for Dyna-METRIC.

(2) Dyna-METRIC Shortcoming. The "Achieved" line for Dyna-METRIC in Figure 3-2 falls to zero, unlike that for PARCOM, due to a Dyna-METRIC shortcoming. In Dyna-METRIC, parts fail as a function of requested rather than achieved flying hours. Consequently, when the fleet can no longer fully meet the flying program, Dyna-METRIC fails a quantity of parts equal to what would have failed had all requested flying hours been flown. This results in a progressively overstated quantity of failed parts, and fleet performance falls off at a faster rate than if calculated with achieved flying hours.

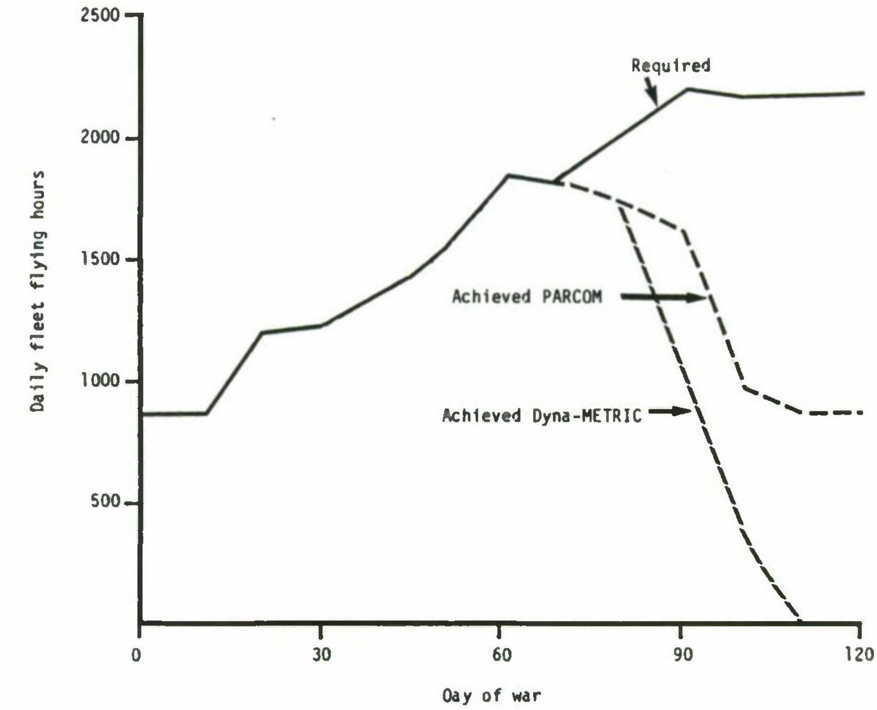

Figure 3-2. Comparison of Capability Assessments; Full Substitution, Dyna-METRIC and PARCOM Models

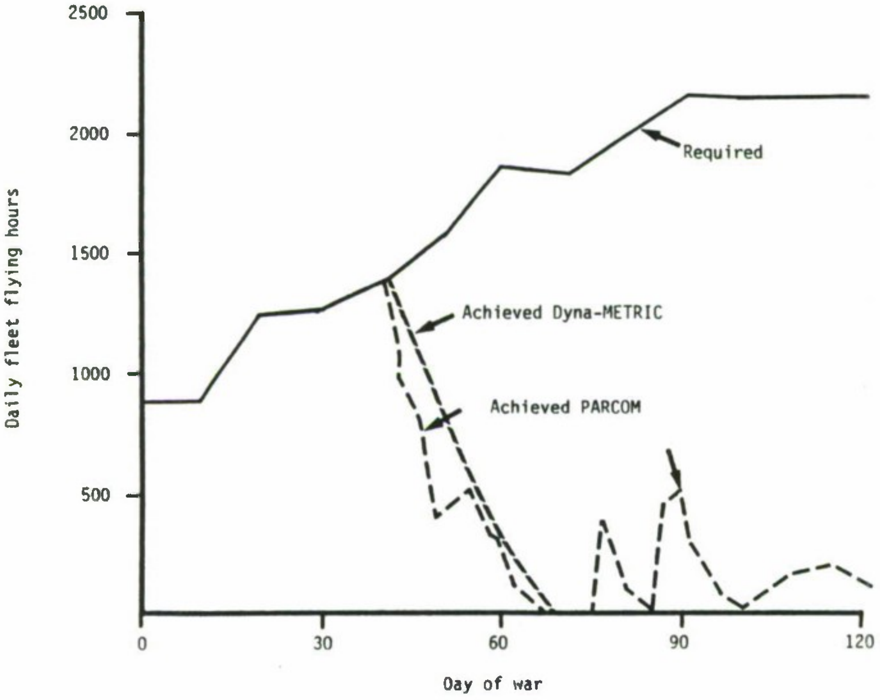

Figure 3-3. Comparison of Capability Assessments; No Substitution, Dyna-METRIC and PARCOM Models

c. Results - Summary. In summary, Dyna-METRIC accurately determined if the flying hour program could be met and, where it could not be met, when the falloff point would occur. Since Dyna-METRIC overstates failures when requested flying hours are not achieved, one cannot deduce the fraction of the total flying hour program achieved over the period modeled. The latter determination is obtained with Overview and PARCOM. One could indirectly obtain this information with Dyna-METRIC by successively running the model with progressively downward-adjusted flying hour programs until 100 percent achievement was obtained. The final flying hour program would be that which is achievable with the given resources.

3-4. REQUIREMENTS ASSESSMENT FOR FULL SUBSTITUTION

a. Introduction. This paragraph describes the comparison of Dyna-METRIC full-substitution requirements assessment results to those of Aircraft Spares.

b. Methodology

(1) Cost Optimization. For this comparison, Dyna-METRIC was requested (through selection of options) to buy only parts for AVUM/AVIM stocks (representing additional prepositioned war reserves) as done in Aircraft Spares. When a need for more mission-capable aircraft is indicated, parts are bought in an optimal manner to minimize cost. The cheapest set of parts which will allow for sufficient mission-capable aircraft to meet the target is bought. For the special case of full substitution, since shortages of parts are consolidated to the fewest number of NMCS aircraft, the part which is causing the greatest number of NMCS aircraft must always be bought first.

(2) Goal Specification. Dyna-METRIC buys to achieve a user-specified availability (fraction of fleet aircraft which are flyable) target. Overview buys to meet a flying hour program. PARCOM buys to meet either an availability target or a flying hour program or both. The comparison desired for this test was against the objective of meeting a flying hour program. To do this with Dyna-METRIC, a manual calculation determined the minimum availability target which would allow the flying hour program to be met. This is determined using the daily flying hours requested, the daily aircraft on hand (deployed aircraft minus attrited aircraft), and the maximum daily flying hours allowed for each mission-capable aircraft. The highest availability for any day over the period modeled was used as the availability target.

c. Results

(1) Sustainability versus Cost. Figure 3-4 compares the results of Dyna-METRIC and PARCOM in terms of the cost of additional parts needed to fully meet the flying hour program through different periods. Excellent agreement was obtained, as judged from the small differences in cost. Overview did not generate these type results.

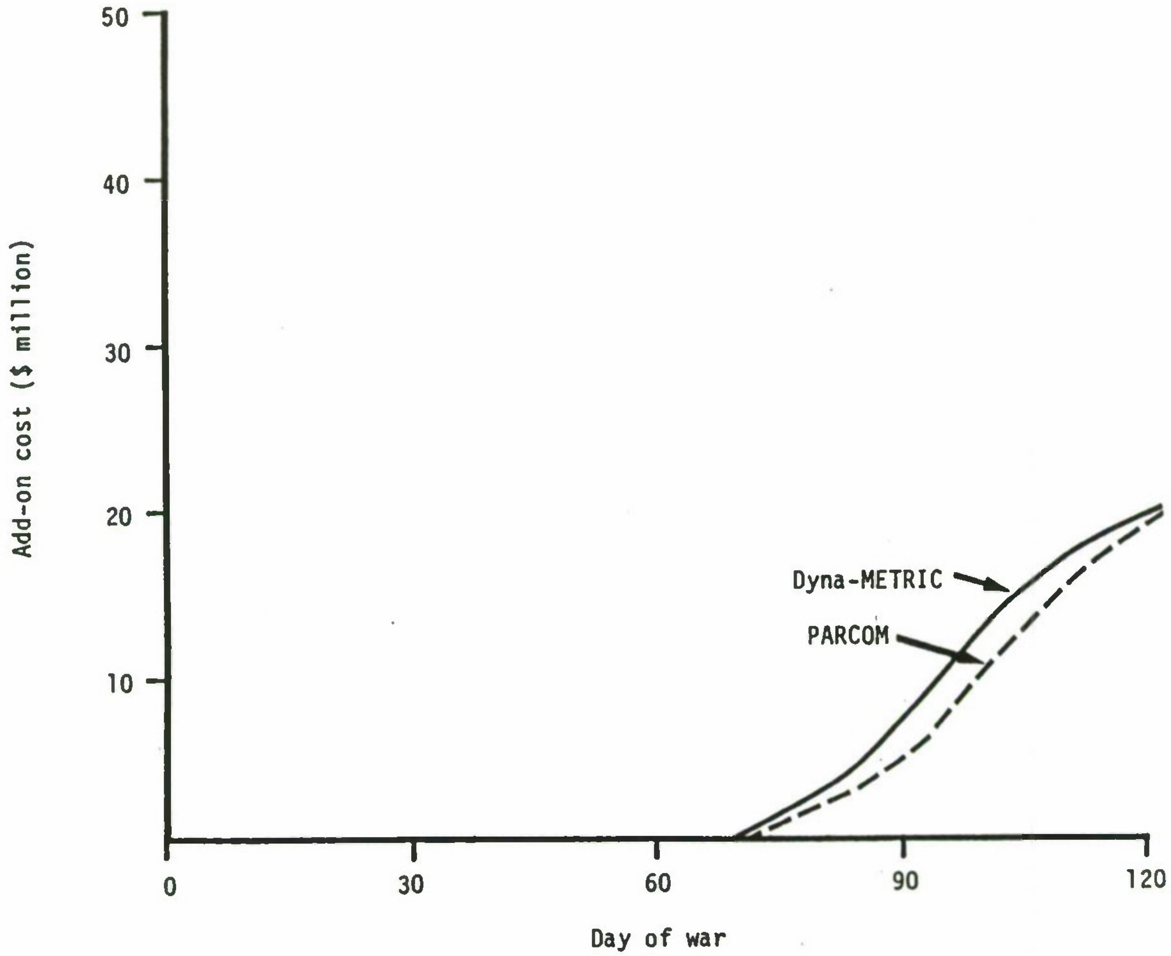

Figure 3-4. Comparison of Aircraft Spares Cost Estimates to Achieve Wartime Flying Hour Programs; Full Substitution, Dyna-METRIC and PARCOM Models

(2) **Parts Required.** Table 3-1 identifies the additional parts and their quantities determined by Dyna-METRIC and PARCOM to be needed in prepositioned war reserves in order to fully meet the flying hour program for the full 120 days. These results are considered an excellent match. When Dyna-METRIC quantities were compared to those of PARCOM and Overview (not shown), all numbers matched closely and, in all cases, Dyna-METRIC values fell in the range between those of PARCOM and Overview.

Table 3-1. Comparison of Aircraft Spares Required; Full Substitution, Dyna-METRIC and PARCOM Models

Part	Dyna-METRIC			PARCOM		
	Quantity	Total cost ($)	Percent of total requirement	Quantity	Total cost ($)	Percent of total requirement
Stability control amplifier	242	19,503,264	99	246	19,825,632	99
Battery	88	57,816	<1	91	59,787	<1
Transducer, engine 1	106	44,732	<1	109	45,998	<1
Transducer, engine 2	23	11,063	<1	30	14,430	<1
Transducer	88	11,000	<1	94	11,750	<1
Hose assembly, nonmetalic	292	9,344	<1	296	9,472	<1
Total		19,637,219			19,967,069	

3-5. REQUIREMENTS ASSESSMENT FOR NO SUBSTITUTION

a. **Introduction.** This paragraph describes the comparison of Dyna-METRIC no-substitution requirements assessment results with those of Aircraft Spares.

b. **Methodology.** The availability target used for this assessment was the same as for the full-substitution requirements run just discussed. Dyna-METRIC bought the cheapest set of parts which would allow for sufficient mission-capable aircraft to meet the target.

c. **Results**

(1) **Sustainability versus Cost.** Figure 3-5 compares the results of Dyna-METRIC and PARCOM in terms of the cost of additional parts needed to fully meet the flying hour program through different periods. As with full substitution, the figure shows excellent agreement between the results of the two models. No-substitution computations cannot be obtained with Overview.

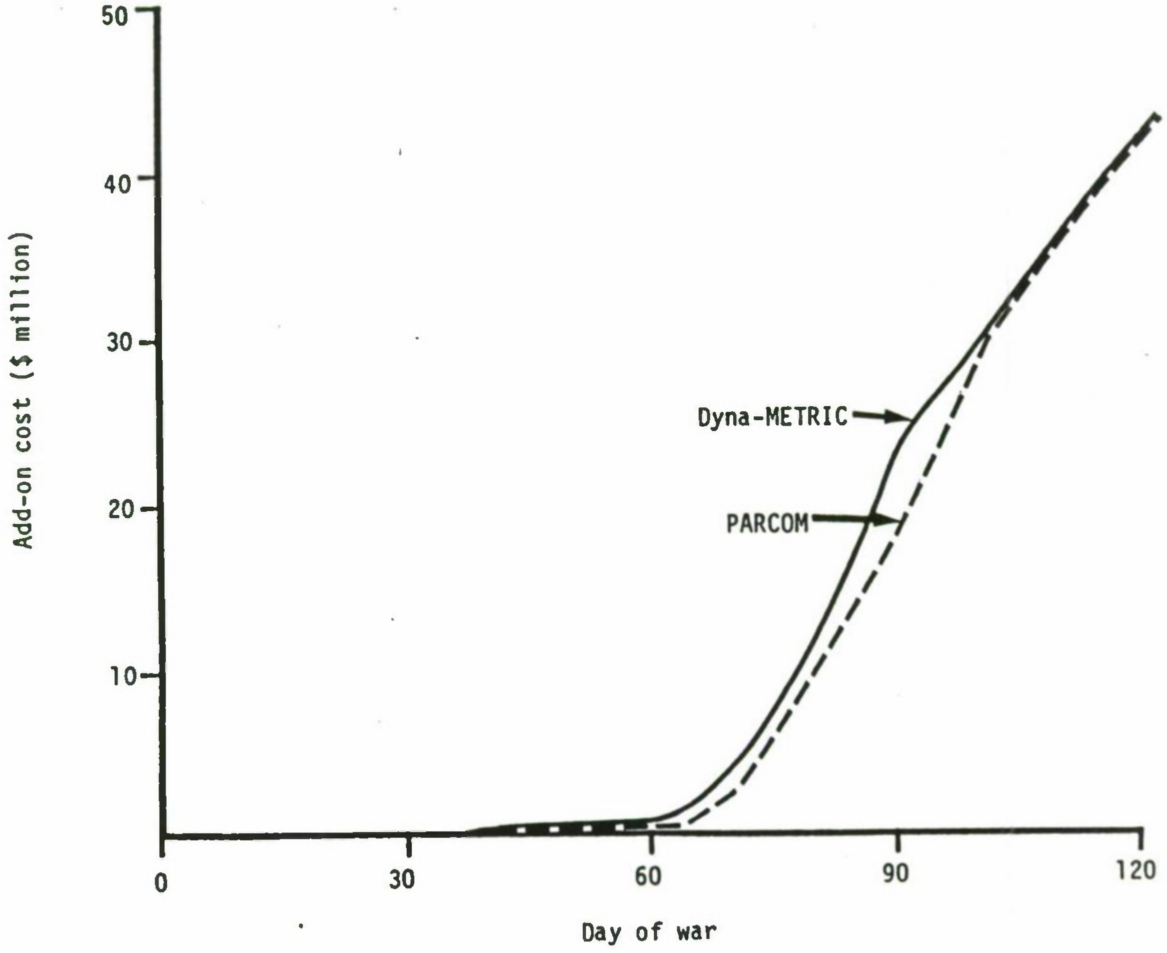

Figure 3-5. **Comparison of Aircraft Spares Cost Estimates to Achieve Wartime Flying Hour Program; No Substitution, Dyna-METRIC and PARCOM Models**

(2) **Parts Required.** Table 3-2 identifies the additional parts and quantities of each determined by Dyna-METRIC and PARCOM to be needed in prepositioned war reserves to fully meet the flying hour program for the full 120 days. For brevity, only the first six parts are listed in the table. The parts are listed in order of decreasing unit purchase cost. A large number of different parts were bought by both models as indicated. Although the total dollar costs for the two models agree closely, the specific parts bought differ significantly. The difference may be due to the probabilistic nature of the Dyna-METRIC computations compared with PARCOM's purely deterministic solution. No-substitution computations cannot be obtained with Overview.

Table 3-2. Comparison of Aircraft Spares Required; No Substitution, Dyna-METRIC and PARCOM Models

Part	Dyna-METRIC			PARCOM		
	Quantity	Total cost ($M)	Percent of total requirement	Quantity	Total cost ($M)	Percent of total requirement
Stability control amplifier	379	30.54	71.0	386	31.11	72.3
Transmission assembly	126	6.42	14.9	137	6.98	16.2
Hub assembly main rotor	28	1.04	2.4	30	1.11	2.6
RT-1157/APX-100	7	0.06	0.1	6	0.05	0.1
Feeder assembly gun	51	0.39	0.9	44	0.33	0.8
Gun control assembly	53	0.40	0.9	42	0.32	0.7
		38.85	90.2		39.90	92.7
Total for all parts	$43.00 million (160 part types)			$43.09 million (98 part types)		

CHAPTER 4

EXAMINATION OF PARTIAL SUBSTITUTION

4-1. GENERAL. This chapter describes the testing performed to meet the principal objective--to determine if Dyna-METRIC can represent a partial-substitution part replacement policy. The two policies, full substitution and no substitution, considered in the Aircraft Spares Study and discussed earlier in this report, represent the bounding limits of controlled substitution. Neither is an accurate portrayal of what would occur in wartime. Full substitution is an optimistic policy, especially when applied as if the entire theater had a single stockpile of aircraft and parts, as is assumed by Overview and PARCOM. No substitution is a conservative, worst-case replacement policy.* It assumes parts may never be removed from one aircraft to fix another. Reality lies somewhere between full and no substitution. In partial substitution, some parts could be "borrowed" from other NMCS aircraft and some could not. Exactly how much controlled substitution would occur in wartime is not known. The current Army regulations on controlled substitution limit the practice to a few exceptional cases. It is not known, however, to what extent the regulations would be adhered to in a combat environment.

4-2. DYNA-METRIC PARTIAL-SUBSTITUTION FEATURES. Dyna-METRIC can model partial substitution only in the capability assessment mode. According to Rand, partial substitution in the requirements assessment mode is not currently provided, not because of programing difficulties, but due to a combination of lack of demand from users and controversy in defining the process whereby parts would be purchased under such conditions. In the capability assessment mode, Dyna-METRIC represents partial substitution differently for major assemblies (LRUs) and subassemblies (SRUs and sub-SRUs). For LRUs, the user designates each part as either substitutable or not. LRUs which are designated as substitutable may be freely substituted at any base, but not between bases. For SRUs and sub-SRUs, the user designates bases, CIRFs, and depots as allowing substitution or not. Each base, CIRF, and depot, where substitution is allowed, can freely substitute SRUs and sub-SRUs as necessary within its own facility, but not with another facility (base, CIRF, or depot). For this test, all parts were treated as if they were LRUs.

4-3. CASES EXAMINED

a. NRTS Criterion Only. The evaluation performed here started with the same scenario representation described in Chapter 3. First, only parts whose NRTS rates were greater than 50 percent were allowed to be substituted. This identified 60 of the total 334 parts as substitution candidates. The capability assessment results were very close to those for the previously described no-substitution case.

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*However, having all parts in a single accessible stockpile ameliorates this somewhat, i.e., separate AVUMs and AVIMs is worse still.

b. NRTS and Repair Time Criteria. A second, two-criterion policy was defined which included as substitution candidates all parts meeting the NRTS criterion and, additionally, any part whose base (AVIM/AVUM) repair time was 30 days or longer. The latter category fit 45 parts. The total number of parts qualifying as substitutable for the two criteria was 104 (one part satisfied both criteria). The results follow.

4-4. PARTIAL-SUBSTITUTION CAPABILITY ASSESSMENT

a. Comparison With Full and No Substitution. The results of the two-criterion partial-substitution policy are compared in Figure 4-1 to the Dyna-METRIC results for no substitution and full substitution and, as expected, lie between those bounding conditions. A peculiarity of the no-substitution calculations is discussed further in Chapter 5, paragraph 5-4.

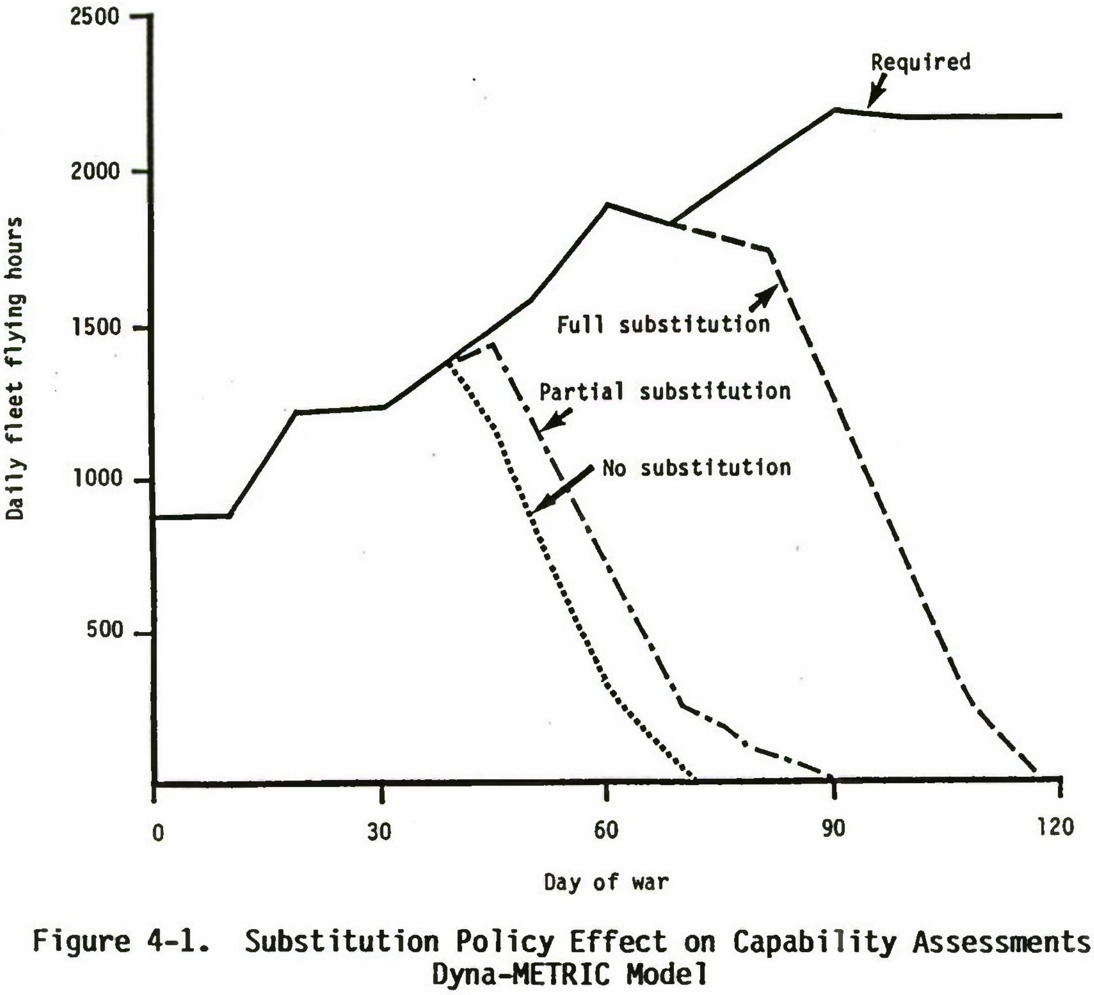

Figure 4-1. Substitution Policy Effect on Capability Assessments; Dyna-METRIC Model

b. Comparison With PARCOM Results. Figure 4-2 compares the Dyna-METRIC partial-substitution solution to that of extended PARCOM with the same substitution criteria. The most significant feature is the point at which the models predict that the fleet can no longer fully meet the flying hour program. The Dyna-METRIC breakpoint at day 45 is close to that for PARCOM at day 42. The difference in the falloff of the two curves is due to (1) subtle differences in how the two models represent the scenario, (2) differences in how the models apportion shortages across on-hand aircraft, and (3) the Dyna-METRIC shortcoming whereby parts fail as a function of requested rather than achieved flying hours. Analysis of other cases and manual calculations (not reported here) confirm that the computations by both models are proper.

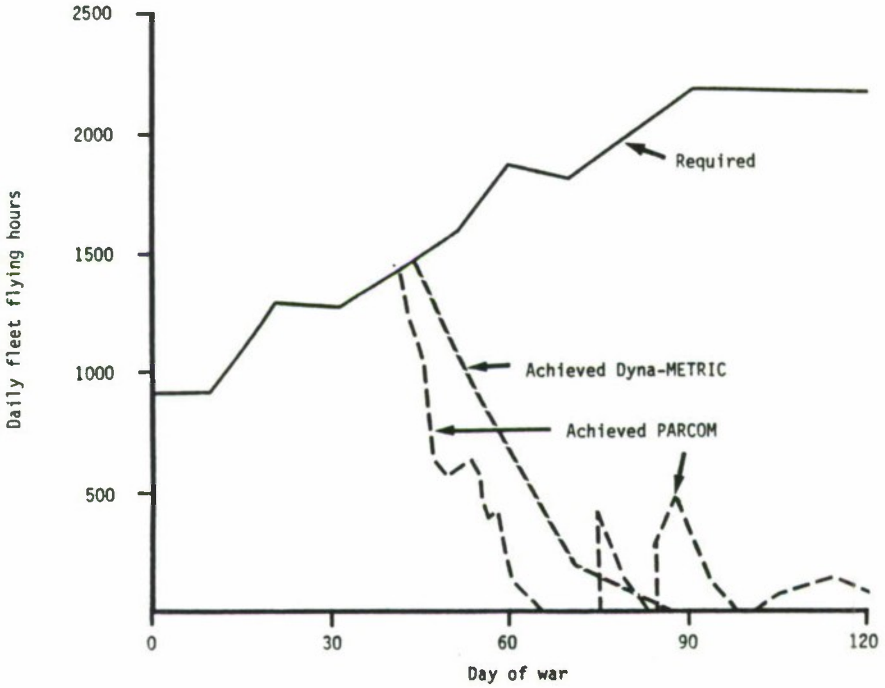

Figure 4-2. **Comparison of Capability Assessments; Partial Substitution, Dyna-METRIC and PARCOM Models**

c. Summary of Results. The above results demonstrate that Dyna-METRIC can represent partial substitution in a capability assessment mode. The results further suggest, at least for the scenario played, that no substitution is a close approximation to the selected partial-substitution policy. It would appear that some other criterion than the ones used, say parts failure rate, might achieve greater sustainability or total flying hours when designating parts as substitutable. However, the tests conducted appear to show that the capability assessment methodology for partial substitution is proper.

4-5. PARTIAL-SUBSTITUTION REQUIREMENTS ASSESSMENT

a. Not Directly Feasible with Dyna-METRIC. As mentioned in paragraph 4-2, and for the reason stated, Dyna-METRIC does not presently have the capability to directly compute requirements for partial substitution. Rand believes, however, that it is feasible to add the feature to the model.

b. A Workaround Approach. Dyna-METRIC could be used indirectly to determine partial-substitution requirements by repeatedly performing partial-substitution capability assessment runs with progressively more select parts added until the desired flying hour program or availability target is achieved. This process, although feasible, is laborious and may be impractical.

CHAPTER 5

EXCURSIONS

5-1. GENERAL. This chapter describes excursions with Dyna-METRIC which, while not directly addressing the stated test objectives, were felt to be of particular interest. These additional runs investigated the effects of variations of three key variables: (1) availability target, (2) confidence level goal, and (3) substitution policy. Except for these three key variables, all runs described here conformed to the same basic scenario representation previously described.

5-2. EFFECT OF VARIATIONS IN OPERATIONAL AVAILABILITY TARGETS. Figure 5-1 shows the effect of variations in operational availability targets on the results of the no-substitution requirements determination. For each case, Dyna-METRIC determined what additional parts were needed as prepositioned war reserves for the aircraft fleet to be able to fully meet the requested flying hour program while also maintaining the specified availability. Plotted for each case are the add-on costs for those parts needed to sustain the fleet for the indicated number of days. The total costs to meet the flying hour program for 120 days while also achieving specified availability levels ranged from $44.7 million for 50 percent availability to $75.3 million for 90 percent availability. For the case shown, then, a substantial increase in cost is associated with achieving increased availability levels.

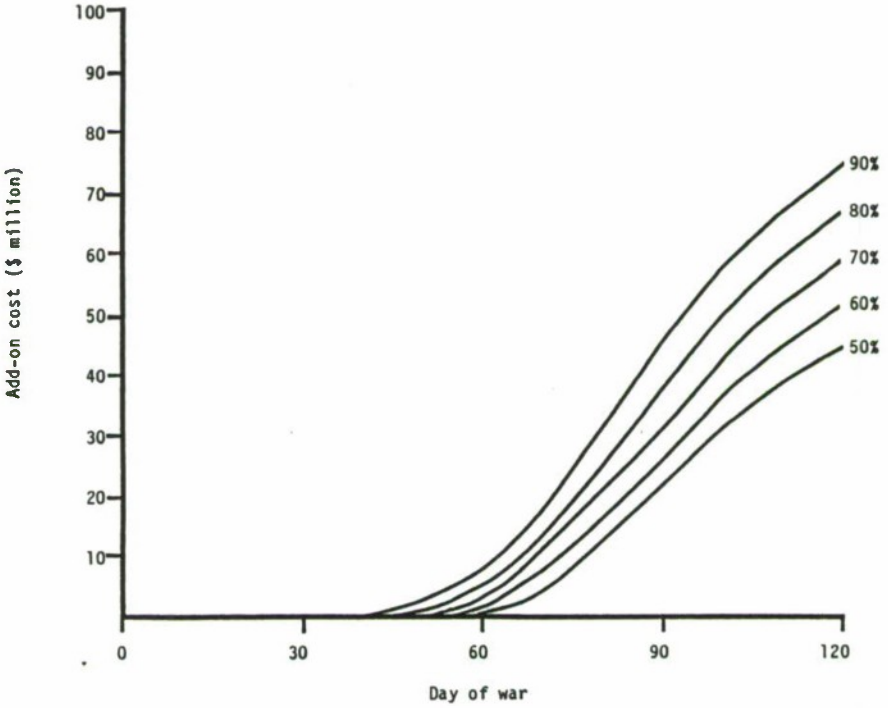

Figure 5-1. Cost Estimates to Meet Various Availability Goals; No Substitution, Dyna-METRIC Model, 50 Percent Confidence

5-3. EFFECT OF VARIATIONS IN CONFIDENCE LEVEL GOALS. Figure 5-2 shows the effect on the results of the full-substitution requirements determination due to variations in the requested confidence level. Plotted for each case are the add-on costs needed to sustain the fleet for the indicated number of days. The total cost to meet the flying hour program for 120 days at 50 percent confidence is $19.6 million. For 90 percent confidence, the total cost is $22.2 million, an increase of $2.6 million. In the case shown, then, at little additional cost, a large increase in confidence in meeting the availability objective can be attained.

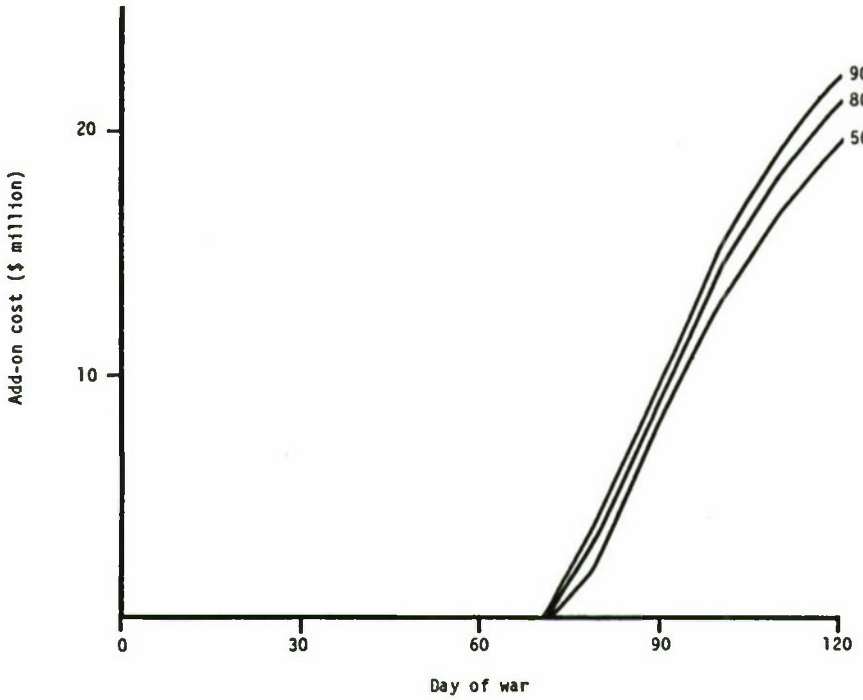

Figure 5-2. Cost Estimates to Increase Confidence Level; Full Substitution, Dyna-METRIC Model, 50 Percent Availability

5-4. EFFECT OF DIFFERENT CONTROLLED SUBSTITUTION POLICIES. As with Figure 4-1, Chapter 4, Figure 5-3 compares Dyna-METRIC capability assessment results for each of three substitution policies. Plotted again are the requested fleet flying hours per day and the hours that could be achieved with current resources. The policies are: (1) full substitution, where all parts could be freely substituted, (2) partial substitution, where only select parts, whose NRTS rate exceeded 50 percent and/or whose base (AVUM/AVIM) repair time was 30 days or longer, could be substituted, and (3) no substitution, where substitution was not allowed. In Figure 5-3, however, the no-substitution results were computed two different ways. The NMCS-based no-substitution results correspond to randomly distributing shortages across all on-hand aircraft. With this technique (characteristic of Dyna-METRIC), multiple shortages can appear on single aircraft even though substitution is not allowed. This technique is considered more realistic than the backorder-based technique (characteristic of PARCOM) in which no consolidation of shortages due to chance is allowed. The difference between the two techniques becomes greater as time progresses, since, as an increasing number of shortages is distributed over the same or fewer on-hand aircraft, more consolidation results for the NMCS-based technique. The backorder-based technique is always a more conservative statement of capability.

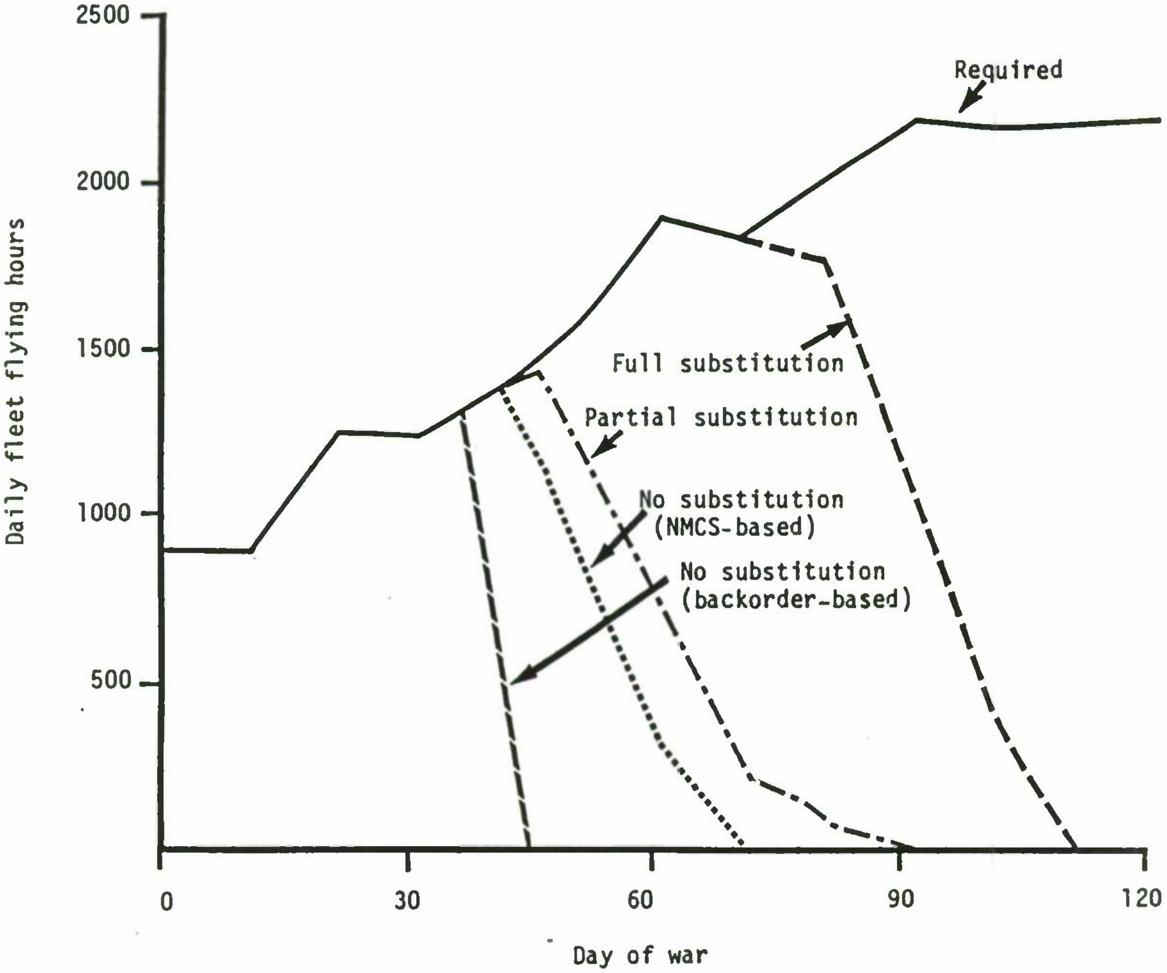

Figure 5-3. Capability Assessments of Current Inventory; Full, Partial, and No Substitution, Dyna-METRIC Model

CHAPTER 6

STRENGTHS AND SHORTCOMINGS OF DYNA-METRIC

6-1. INTRODUCTION. This chapter compares the important features of Dyna-METRIC to those of extended PARCOM, which provides for partial-substitution computations and removes remaining deficiencies when compared with Overview. The Overview Model has been excluded from this discussion since extended PARCOM effectively supersedes Overview. Use of "PARCOM" in this chapter is synonymous with "extended PARCOM."

6-2. FEATURES IN COMMON WITH PARCOM. Presented in this section are key attributes common to both Dyna-METRIC and PARCOM.

a. Variable Flying Hour Program. Both models allow the user to specify a fleet flying hour requirement which can vary throughout the war, PARCOM on a daily basis, Dyna-METRIC at selected discreet points in time.

b. Phased Deployment of Aircraft. With both models, the fleet size can vary to represent phased deployment of aircraft assets (PARCOM daily, Dyna-METRIC at discreet points).

c. Phased Deployment of Parts. With both models, depot stocks can either be pushed forward to the retail echelon at the outset of war or they can be held back at depot until requisitioned. Retail assets associated with deploying units can be phased in with the unit (except as discussed in paragraph 6-4h).

d. Variable Attrition. Both models allow aircraft attrition to vary (PARCOM daily, Dyna-METRIC at discreet intervals).

e. Full, No, and Partial Substitution. Both models can represent full-, no-, and partial-substitution part replacement policies (except that for partial substitution, Dyna-METRIC allows for capability assessment but not requirements assessment; see 6-4a).

f. Constrained and Unconstrained Cost. Both models can determine the cheapest mix of parts to buy to maximize performance given a limited or unlimited dollar amount.

g. Availability Goal. Both models can compute the parts required to achieve and sustain a minimum aircraft availability level.

h. Days of Sustainability. Both models can compute the number of days that a specified flying program can be fully met for a given set of resources.

i. Summary of Common Features. The features a through d above represent important dynamic aspects of wartime. Most logistics models are peacetime oriented and do not allow the flexibility to represent these factors as regularly varying quantities. Features e through h are necessary in order to answer the basic questions posed in the Aircraft Spares Study (see Table 1-1, Chapter 1).

6-3. DYNA-METRIC STRENGTHS. Table 6-1 summarizes the strengths of Dyna-METRIC relative to PARCOM. Only features considered relevant to potential Army applications are included. An attempt was made to list the features in order of relative importance. Such a ranking, of course, is very subjective. Some of the strengths in Table 6-1 are based on experience gained from this testing effort. As indicated, certain features are based largely on review of Dyna-METRIC documentation and claims therein. Each strength is described below.

Table 6-1. Dyna-METRIC Strengths

Probabilistic pipeline representation
Randomized repair and transportation times
Random distribution of shortages
Confidence levels
Discrete modeling of facilities within an echelon
Three repair echelons
Limited modeling of repair resources[a]
Geographically limited substitution[a]
Multiple indenture levels[a]
Temporary transportation cutoff[a]
Peacetime pipeline initialization[a]
Three-echelon stock purchasing
Variable mission types[a]
Limited depot throughput[a]

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[a] Determination based largely on review of documentation.

a. **Probabilistic Pipeline Representation.** Dyna-METRIC distributes the occurrence of failures according to a user-specified distribution, either Poisson, binomial, or negative binomial, by specifying the associated variance-to-mean ratio for each LRU. Thus, part failure rates and pipeline distributions are treated probabilistically. PARCOM, in contrast, fails parts at a constant rate per hour flown, based on a specified expected-value failure rate. A caveat to this strength is that the selection of distribution type is controversial. Army data is such that one cannot readily determine the variance-to-mean ratio.

b. **Randomized Repair and Transportation Times.** Dyna-METRIC allows the user to select whether repair and transportation times should be fixed, as with PARCOM, or randomized. When fixed is selected, repair and transportation times are always precisely the value entered. When randomized, Dyna-METRIC distributes these times.

c. Random Distribution of Shortages. With Dyna-METRIC, holes for each part are randomly distributed across all on-hand aircraft. Hole, as used here, refers to a net part shortage which causes a NMCS aircraft. The result is that more than one hole can occur on a single aircraft. This leads to a more realistic, and more optimistic, determination of total NMCS aircraft than if only one hole was allowed per aircraft. PARCOM bases its calculations on the latter one-hole-per-aircraft technique. This discussion is not relevant when considering full substitution, since, for that case (by definition), holes are consolidated to the minimum number of aircraft. It is relevant for no substitution, where no further hole consolidation is introduced, and for partial substitution, where only holes due to select parts are further consolidated. Results based on both computation techniques can be extracted from Dyna-METRIC output. Random distribution is assumed in the model's calculations of expected NMCS aircraft, expected hours flown, etc. To assign only one hole to an aircraft, however, one must manually recalculate these results at each reporting period based on the reported "total back orders" value, which represents the total holes.

d. Confidence Levels. Since Dyna-METRIC treats many aspects of the logistics system probabilistically, it can, and does, associate confidence levels with all of its performance results. For requirements assessments a confidence limit is entered with the availability target.

e. Discrete Modeling of Facilities Within an Echelon

(1) Description. PARCOM aggregates all aircraft units and retail repair facilities (AVUMs and AVIMs) into a single entity. Dyna-METRIC, on the other hand, allows distinct representation of all three echelons (see f) and, within each echelon, allows discrete representation of organizational elements. So one can separately represent each AVIM (as a CIRF, in Dyna-METRIC terms) at the intermediate echelon, and each aircraft unit with its AVUM (as a base, in Dyna-METRIC terms) at the unit echelon. Dyna-METRIC allows grouping from full discreteness to full aggregation.

(2) Benefits. Potential benefits include consideration of interorganization shipping delays and accurate representation of different stock levels, demands, and repair performance factors (repair times, NRTS rates, condemnation rates). Another benefit is that full and partial substitution are more accurately portrayed, since Dyna-METRIC limits substitution to within a distinct repair facility. With aggregation, effects of substitution are overstated, because substitution is allowed across all aggregated units and repair facilities.

(3) Drawbacks. There are two important caveats to the benefits of discrete modeling:

(a) The added complexity of modeling 70 or more separate AVUMs and AVIMs, as required for a discrete Army theater representation, would result in very long Dyna-METRIC run times (estimated at 6 hours or more).

(b) The additional data needed to individually describe AVUMs and AVIMs is extremely difficult to obtain. Practicality would probably dictate the use of estimates.

(4) Practical Approaches. There are some compromise approaches in which the benefits of being able to model discrete units could be obtained without incurring some of the major difficulties.

(a) Partial aggregation could be used--a corps aggregation instead of full theater aggregation, for example.

(b) Where several aircraft units and AVUMs can be assumed to be identical, they can be represented as replications of a single base. For this situation Dyna-METRIC data requirements and most computations would be treated as if only the first base of the set were present. Later, adjustments would be made to account for the full set.

(c) A combination of the above two approaches could be used.

f. Three Repair Echelons. Dyna-METRIC allows for the distinct representation of depots, CIRFs (AVIMs), and bases (AVUMs). PARCOM, in contrast, combines AVIMs, aircraft units, and AVUMs into a single retail entity. The benefits, drawbacks, and practical approaches, discussed in the previous section on discrete modeling of facilities within an echelon, apply equally well to this feature.

g. Limited Modeling of Repair Resources. This Dyna-METRIC feature (not tested) is the ability to adjust part repair times based on the availability of repair resources. (See also paragraph n for a technique for constraining depot throughput.) A repair resource can be test equipment, a test or repair team, or an individual with a specific military operational specialty (MOS). Each part is designated as requiring the availability of specific repair resources. If the needed resources are not available, the repair is held up until they are available. More investigation is needed to answer the following very important questions:

(1) What degree of resolution can be represented in Dyna-METRIC without exceeding practical limits on entering data and without exceeding acceptable run time demands?

(2) Can Army data supporting the selected resolution be practically obtained?

h. Geographically Limited Substitution. Dyna-METRIC limits substitution of parts to within a repair facility. If Army aircraft units and AVUMs are discretely represented as separate bases, then substitution, when allowed, is limited to within the organization at the base. The greater the aggregation of organizations at base level, the more widespread the allowed substitution. Unlimited substitution across all organizations, as is allowed with PARCOM, is unrealistic. Paragraph 6-3e discussed practical difficulties of discrete representation of organizations.

i. **Multiple Indenture Levels.** Another untested Dyna-METRIC feature is the ability to represent part assemblies as a hierarchical structure. Dyna-METRIC treats parts as LRUs, SRUs, and sub-SRUs. An LRU is composed of SRUs and an SRU is composed of sub-SRUs. PARCOM treats only LRUs. Subordinate parts are consolidated into the LRUs as required. This testing of Dyna-METRIC considered only LRUs. More investigation is needed to determine (1) how large a force structure could practically be modeled with Dyna-METRIC if indenture was included, and (2) can supporting Army data practically be obtained.

j. **Temporary Transportation Cutoff.** Dyna-METRIC allows the user to specify that any part transportation route be severed for a specified period of time. This feature was not tested.

k. **Peacetime Pipeline Initialization.** Dyna-METRIC allows the option to model a steady-state peacetime force structure and flying hour rate prior to the wartime period. This feature effectively computes the initial fill for the various repair and supply pipelines. Initial pipeline fills can also be manually entered. Initializing the pipelines based on a peacetime lead-in period should produce more accurate fleet performance computations.

l. **Three-echelon Stock Purchasing.** Dyna-METRIC, in its requirements assessment mode, allows the user to specify the purchasing of stock for placement in any of the echelons played. One check run showed Dyna-METRIC could buy parts to be placed at depot. All other testing simulated the buying of parts representing prepositioned war reserves placed at base.

m. **Variable Mission Types.** This feature, which was not tested, allows for the definition of up to five mission types for each aircraft. Parts are designated as essential or not for each mission type. Aircraft at each base may be assigned any or all missions. Using this feature, Dyna-METRIC can examine partial-mission-capable-aircraft questions. A shortage of parts may cause an aircraft to be not fully mission-capable, but the aircraft can be capable of performing some designated mission types.

n. **Limited Depot Throughput.** This feature, which was not tested, allows the user to constrain the number of each part that can be repaired by a depot over time. This depot throughput control can be specified in two ways: (1) a throughput factor can be specifically entered for each part; (2) wartime depot throughput can be specified as the peacetime throughput multiplied by a given factor (greater or less than 1). This feature could be used to model constrained repair resources.

6-4. Dyna-METRIC SHORTCOMINGS. Table 6-2 summarizes the shortcomings of Dyna-METRIC relative to PARCOM. All of these shortcomings were identified or verified through testing. Each is discussed below.

Table 6-2. Dyna-METRIC Shortcomings

Partial substitution limited to capability assessment
Availability target only
Failures based on requested hours
Slightly greater effort to install and operate
Longer run times
Limited precision for failure rates and flying hours
Difficult to enter more than 10 aircraft or flying hour levels
No phased deployment of parts for aggregated theater representation

a. Partial Substitution Limited to Capability Assessment. For partial substitution evaluations, Dyna-METRIC is limited to capability assessment. No partial substitution requirements assessment mode is provided. (Paragraph 4-5 included a possible workaround solution to this limitation.)

b. Availability Target Only. When performing a requirements assessment, Dyna-METRIC and PARCOM purchase parts to meet one or more specified goals. Dyna-METRIC allows specification of only one type of goal--fleet aircraft availability (or NMCS). The availability target must be met while flying all the requested hours. PARCOM allows specification of two goals--fleet aircraft availability and flying hour accomplishment, separately or together. Refer to paragraph 3-4c for a discussion of how the requirements goal was used for answering the Aircraft Spares questions.

c. Failures Based on Requested Hours. Dyna-METRIC computes part failures as if the entire requested flying hour program were achieved. This is not a concern in the requirements assessment mode, since parts are bought to meet a stated availability when all hours are flown. In the capability assessment mode it **is** a concern, since requested hours are not always achieved. The result is that more failures are accrued than should be whenever all required hours are not flown. This does not affect the determination of how long the flying program is fully met. But once the program is no longer fully achieved, failures are overstated. This precludes a correct computation of the fraction of the total flying hours achieved over the whole war. (See also paragraphs 3-3b and 3-3c. Paragraph 3-3c contains a workaround solution for this problem.)

d. Slightly Greater Effort to Install and Operate. Dyna-METRIC is a much larger computer program than PARCOM (37,000 versus less than 2,000 lines of code) and, as a result, installation and operation can present added difficulties. Because Dyna-METRIC is highly transportable (well written, documented, maintained, and supported), these difficulties are minimized. Data requirements and preparation are the same for both models. Appendix C discusses the experience this organization had with installing and operating the model. When compared to PARCOM, for purposes of answering the Aircraft Spares Study questions, Dyna-METRIC output contains much superfluous information, and it is not customized for that type of problem. For these reasons, Dyna-METRIC output is considerably more difficult to interpret than that of PARCOM.

e. Longer Run Times. Dyna-METRIC run times are significantly longer than for PARCOM, and more Dyna-METRIC runs are needed to produce the same collection of computations included in a single PARCOM run. PARCOM typically runs in less than 2 minutes' CPU time. Capability assessment runs for Dyna-METRIC for the scenario used for this test were around 6 minutes' CPU time. Requirements assessment runs for the same scenario with Dyna-METRIC ranged up to 10 minutes. Dyna-METRIC run times will increase dramatically for more complex scenario representations. Run time is dependent on the number of different part types, bases, CIRFs, and depots, and on the length of period simulated. A detailed Army theater representation with Dyna-METRIC could require several hours' CPU time.

f. Limited Precision for Failure Rates and Flying Hours. Dyna-METRIC input formats are defined such that they allow one less significant digit than desired for specifying part failure rates (demand rates) and requested daily flying hours (sortie rates). This is responsible for some discrepancies between PARCOM and Dyna-METRIC results (discussed in Chapter 3). For one critical part, for example, this amounted to a 2 percent error in the failure rate. Although this percentage error seems low, when applied against 200,000 flying hours, a discrepancy of several failures can result. If the part has a very high unit cost, requirements costs can be significantly affected. This shortcoming can be removed by changing the input formats.

g. Difficult to Enter More than 10 Aircraft or Flying Hour Levels. Dyna-METRIC input format requirements are such that it is difficult to enter more than 10 values for several scenario variables. This was a problem in specifying aircraft deployment levels and requested flying hours (sortie rates). While the model theoretically has no data input limitation, there are practical difficulties in creating and editing long lines of input data on some computers. Aircraft levels, for example, are entered on a single line for each base. The more aircraft levels, the longer the line. Due to the manner in which Dyna-METRIC scans input lines, a fix is a little more involved than one might think. Nevertheless, the problem could be fixed by Rand with a moderate effort. For purposes of this test, a crude fix was implemented.

h. No Phased Deployment of Parts for Aggregated Theater Representation. This is only a problem for the aggregated theater representation (undertaken to provide the same scenario as for PARCOM), where all AVUMs and AVIMs are represented as a single base. Bases and CIRFs as a whole can be modeled as entering the war at a delayed time. When AVUMs and AVIMs are discretely represented as separate bases and CIRFs, then one can individually delay the arrival, in effect, of their repair capabilities and part stocks. But, when lumped together, there is no way of selectively withholding some stock and repair capability until a later date.

CHAPTER 7

CONCLUSIONS

7-1. AIRCRAFT SPARES THEATER COMPARISON. This test demonstrated that the Dyna-METRIC Model can effectively represent a theater Army helicopter force in wartime. In test runs against the scenario representations of the Aircraft Spares Study, the results from Dyna-METRIC agreed well with those from the Overview and PARCOM Models. The key questions answered in Aircraft Spares can also be answered using Dyna-METRIC.

7-2. PARTIAL SUBSTITUTION. Testing showed that Dyna-METRIC can perform fleet **capability assessments** under a partial-substitution policy. **Requirements assessments** under partial substitution cannot be performed directly with a single run. Consultation with Rand, the model developer, suggests that this feature could be added without any serious difficulty. The model can represent those partial-substitution policies where the candidates for substitution are determined on a part-by-part basis. Based on the available documentation, Dyna-METRIC also can geographically limit substitution to one or a group of discretely represented repair facilities.

7-3. DYNA-METRIC VERSUS OVERVIEW AND PARCOM. A parallel effort under the Overview/PARCOM Turnkey Project resulted in an enhanced version of PARCOM (designated extended PARCOM), which includes the desired partial substitution features as well as other features which allow it to completely replace Overview. Extended PARCOM meets all of the objectives of the original Aircraft Spares Study. Although Dyna-METRIC can do most of what extended PARCOM does and has some additional valuable features, Dyna-METRIC is not recommended for aggregated theater level analysis because it is more difficult to use and interpret than PARCOM.

7-4. RECOMMENDATIONS

a. Use extended PARCOM and not Dyna-METRIC for answering aircraft spares planning and budgeting questions of interest to headquarters decisionmakers. For this application, Dyna-METRIC is adequate but more difficult to use.

b. Develop a capability for using Dyna-METRIC for detailed analyses of the Army aircraft logistic system. Dyna-METRIC has unique features which are potentially valuable for higher resolution analyses than possible with PARCOM. Because testing was limited to a lower resolution problem not exercising those features, further evaluation of Dyna-METRIC is warranted.

APPENDIX A

ACKNOWLEDGEMENT

A-1. The technical work reported here was aided considerably by colleagues at CAA and through support provided by the Rand Corporation. A substantial contribution was made by Saul L. Penn and Harold D. Frear of CAA, who provided direction and consultation throughout the effort. Significant help was also provided by Walter J. Bauman, MAJ Ronald D. McAdoo, MAJ Robert T. Blake, and MAJ Joseph S. Rovansek of CAA.

A-2. The Rand Corporation provided valuable assistance by furnishing a copy of the Dyna-METRIC Model and associated documentation and by making staff available on an as-needed basis to support installation and testing. Initial contacts with Mort Berman, Ray Pyles, Pat Dey, and Karen Isaacson were beneficial to the early planning. Karen Isaacson played a key role throughout this effort, being highly responsive and capable in approximately 50 telephone contacts. She provided needed help with debugging, modifications, and explanations, as the developmental version 4.3 was applied to new scenarios requiring some previously unused model features.

APPENDIX B

DIFFERENCES BETWEEN DYNA-METRIC VERSIONS 3.04 AND 4.3

This appendix summarizes the differences between the current production version of Dyna-METRIC (version 3, release 04) and the newly developed version of that model (version 4, release 3) which was used for this test. This information has not been published previously. It is provided here to assist potential users in the selection of the appropriate model for future applications. The information was provided by Karen Isaacson of Rand. Features are listed in no particular order.

1. **Automatic Time-scaling.** In Version 3.04, the largest time of analysis permitted was equal to DMTIME-2. In Version 4.3, there is no such limit. If a requested time of analysis exceeds DMTIME, automatic time-scaling is invoked. When this happens, the model determines the smallest integer f such that f x the maximum requested time of analysis is less than DMTIME. For example, if DMTIME is 30 and the maximum time of analysis is 45, then f is 2. Then internally, the model treats f days as if they were a single day. (When f is 2, then the first internal day is really days 1 and 2, the second is days 3 and 4, etc.) Impact on results are fairly minimal, except that there may result some smoothing of the dynamics. (When days 1 and 2 are combined into an internal day, the internal day flies the average flying program of the 2 days.)

2. **Depots.** Depots were not available in Version 3.04. When a base (not assigned to a CIRF) or a CIRF ordered a component, it arrived an order and ship time later (unless resupply was cut off, in which case it would arrive an order and ship time after the end of the cutoff). In Version 4.3, depot stock and repair can be analyzed. Thus, near the start of the scenario, while the depot has not exhausted its stock levels, the bases and CIRFs will receive requisitioned components after a retrograde transportation time. Later in the scenario, components may take longer to arrive pending the depot completing repair of a component of the same type.

3. **Maximum Turn Rate by Base.** In Version 3.04, the maximum turn rate (or actually, the maximum sortie rate) per aircraft was the same at each base. In Version 4.3, a different maximum turn rate may be specified for each base.

4. **Multiple Maintenance Types.** In Version 3.04, there were only two maintenance types allowed, RR and RRR. (Note: the only difference in the model, between maintenance types, is when they become available.) In Version 4.3, the user may specify up to DMCHANGE different maintenance types. He can also name them anything he likes. (This is useful for those who do not believe that you can repair an RR component.)

5. **Sub-SRUs.** In Version 3.04 only LRUs and SRUs were permitted. In Version 4.3, another level of component indenture, sub-SRUs, was introduced.

6. **More Components.** Due to poor design in Version 3.04, the number of components that could be analyzed in a single model run tended to be fairly limited due to main storage constraints. Although an infinite number of components cannot be analyzed by Version 4.3, the number of components that can be handled in the same amount of storage is an order of magnitude greater.

7. **Base Dependent QPAs.** In Version 3.04, the aircraft at each base were assumed to be identical (except that different application fractions were allowed). In Version 4.3, different quantities per aircraft per base of each component are permitted.

8. **Scenario Records are Easier to Specify.** For example, on the aircraft level record in Version 3.04, after the final aircraft level was specified, the user had to enter a large day as the time at which the next aircraft level was to go into effect. In Version 4.3, it is not necessary to specify any further information after the final aircraft level.

9. **SRU Records Look Like LRU Records.** In Version 3.04, the SRU description records had substantially different formats than the LRU description records. In Version 4.3, the LRU, SRU, and sub-SRU description records have substantially the same formats, making the input data set easier to read.

10. **Structured FORTRAN.** Version 3.04 was written in a FORTRAN dialect known as RATFOR, then the RATFOR code was run through a preprocessor to generate FORTRAN code. The resulting FORTRAN code was extremely difficult to read, had convoluted IF statements, and in general, was not in a well-written, structured form. Version 4.3, on the other hand, was written in structured FORTRAN, making the code easier to read, maintain, and modify.

11. **Sustained Demand Rates.** In Version 3.04, each LRU had a peacetime and a wartime demand rate. In Version 4.3, each LRU also has a sustained demand rate that goes into effect at a base-dependent time. The main purpose of this demand rate was to aid in the analysis of engines, which will not undergo scheduled maintenance for a period at the start of a war. Later, when scheduled maintenance is resumed, the demand rates will go up.

12. **Peacetime Reparables May Be Deployed After Repair is Deployed.** In Version 3.04, the repair capability and the peacetime pipelines arrived simultaneously at deploying bases. In Version 4.3, the peacetime reparables may also arrive later, or not at all.

13. **Multiple Identical Bases.** In Version 3.04, if one had 10 identical bases, 10 base description records would be required and computer time would be wasted doing the (identical) base level computations 10 times. In Version 4.3, one can include one base description record describing the 10 bases, and the model will "do the right thing" (only do the base level computations once but multiply the demands on depot resources to reflect the multiple bases, etc.).

14. **Onshore and Offshore Bases.** In Version 3.04, there was only one type of base. In Version 4.3, a base may be either "onshore" or "offshore." The only difference (computationally) between an onshore and an offshore base is that they may have different component demand rates.

15. **Replacement Fractions for SRUs (depot) and Sub-SRUs (all echelons).** Demands for SRUs at the depot both come directly from bases (driven by SRU demand rates) and from failed SRUs that are discovered on LRUs that have been NRTSed to the depot. The probability that an SRU on a NRTSed LRU has failed is better described by replacement fraction than by the ratio of the SRU to LRU demand rate.

16. **Separate Base, CIRF, and Depot Repair Times.** In Version 3.04, there was only one repair time specified per component. In Version 4.3, the repair time for a component depends on whether it is being repaired at the base, the CIRF, or the depot.

17. **Condemnation Rates.** In Version 3.04, if a base or CIRF could not repair a component, the component was NRTSed. In Version 4.3, the component may also be condemned. (Both NRTSing and condemning a part results in a demand on supply at the higher echelon. Only NRTSing results in a demand on repair at the higher echelon.)

18. **Level of Repair (LOR) for LRUs.** In Version 3.04, for some reason, level of repair could only be specified for SRUs. In Version 4.3, it may also be specified for LRUs.

19. **Redundant LRUs.** In Version 3.04, if the quantity per aircraft of an LRU was, say, five, all five of those LRUs had to work in order for an aircraft not to be NFMC. In Version 4.3, the user may specify a lower value (three, say) such that, if three of the five are working, the aircraft is not NFMC for that LRU.

20. **Demand Rate Per Sortie.** In Version 3.04 and 4.3, demand rates are only per flying hour. (In Version 4.4, demand rates may be either per sortie or per flying hour.)

21. **NRTS Before or After Test.** In Version 3.04, an LRU had to be delayed the equivalent of a repair time before it could be NRTSed and before any failed SRUs could be discovered. In Version 4.3, the user specifies whether the LRU may be NRTSed (and failed SRUs discovered) without the LRU being delayed by a repair time.

22. **Work Unit Codes.** Work unit codes are read in by Version 4.3 and used in the problem LRUs report.

23. **Partial Cannibalization.*** In Version 3.04, performance was computed for full cannibalization of LRUs and no cannibalization of LRUs. In Version 4.3, the user may specify some LRUs as cannibalizable and some as not, and (in addition to full cannibalization) performance is computed according to this partial cannibalization scheme.

24. **Awaiting Parts (AWP) Always Based on SRU Cannibalization Switch.** In Version 3.04, the option 12 report (compute performance based on purchased stock) assumed full SRU cannibalization no matter what the setting of the SRU cannibalization switch. This is not true in Version 4.3.

25. **LRU Stockage Assuming No Cannibalization.** All the Version 3.04 stockage algorithms assumed full cannibalization of LRUs. In Version 4.3, stock may also be added to assuming a policy of no cannibalization.

26. **Report Daily Demands on Repair and Supply.** Version 4.3 will optionally write a report on the daily demands on repair and supply at bases, CIRFs, and depots.

27. **Stockage Limited Sorties.** In order to compute expected pipeline contents, Version 3.04 assumed that all requested sorties would be flown. Version 4.3 will optionally fly fewer sorties to reflect sorties that could not be achieved.

28. **Data on SRUs and Sub-SRUs in the Problem LRUs Report.** Version 3.04 gave no information about SRUs in the problem LRUs report. Version 4.3 does.

29. **Cutoffs Forward Only, or Both Forward and Retrograde.** In Version 3.04, only forward transportation could be cut off. In Version 4.3, cutoffs may apply to only forward transportation, or to both forward and retrograde transportation.

30. **Multiple ATE LRU Assignments.** In Version 3.04, an LRU could be assigned to, at most, one type of test equipment. In Version 4.3, it may be assigned to multiple types of test equipment.

31. **Base, CIRF-dependent Depot Transportation Parameters.** In Version 3.04, a component ordered from the "depot" arrived an order and ship time later, where order and ship time did not depend on which base or CIRF ordered the part (although it could depend on the type of part). In Version 4.3, the actual transportation time depends on the base or CIRF and depot. Each component may be assigned to a different depot, and to that extent, the transportation time depends on the component. (Note that there may also be a part-dependent delay due to a shortage of stock at the depot.)

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*i.e., "substitution."

APPENDIX C

MODEL INSTALLATION EXPERIENCE

C-1. INTRODUCTION. No major difficulties were encountered loading and testing Dyna-METRIC. Due to the large size of the model and the developmental status of the version used, however, numerous minor difficulties were encountered. To give a clear picture of what was involved, these difficulties are listed below chronologically. A few statements included in the remainder of this appendix are intended for potential users who are experienced FORTRAN programers. Other readers are advised to read the appendix for general content only.

C-2. INITIAL LOADING. The model was received on magnetic tape. Only minor, routine difficulties were encountered reading the tape. Dyna-METRIC, version 4.3, consists of five distinct program modules which are executed sequentially for each model run. The five modules and their sizes (in symbolic form) are:

a. PART (partitioning module), 1,320 lines

b. ECHO (input checking module), 11,580 lines.

c. PIPE (pipeline computation module), 18,070 lines.

d. MOD (modification, compression, restart module), 1,890 lines.

e. REPORT (report writing module), 4,500 lines.

Total 37,360 lines.

Excellent documentation describing loading procedures, input formats, and a test problem was received with the model.

C-3. MODEL SIZING. In order to allow the model to be run in its minimum size configuration for a particular problem application, Dyna-METRIC is delivered with dummy array dimensions. Sizes must be specified for 27 dummy dimensions which affect literally hundreds of array declarations in DIMENSION and COMMON statements throughout the modules. The necessary sizing was performed quickly and effortlessly with a computer text editor. Selecting the correct sizes is more difficult (see C-8).

C-4. IBM-PECULIAR REFERENCES. Three references to an IBM-peculiar utility routine, ERRSET, had to be deactivated. The affected statements were for the purpose of suppressing harmless underflow warning messages and were inadvertently left in the version delivered (according to Rand).

C-5. ANSI NON-STANDARD LANGUAGE. The model was compiled using a UNIVAC compiler option which flags every occurrence of non-standard ANSI FORTRAN 77 usages.[8] This was done as a check on the transportability of the model. A program which conforms to the standard can reliably be installed and run on any computer with an ANSI FORTRAN 77 compiler. Dyna-METRIC proved to be exceptionally "clean." The rare exceptions noted typically involved "normal" FORTRAN usages which would in no way hamper installation on most computers.

C-6. UNIVAC-PECULIAR FILE FORMATS. Peculiar to the UNIVAC computer used for this test are default file attributes for several FORTRAN logical units used by Dyna-METRIC. The defaults conflicted with the model's intended use. The author had surprising difficulties overriding the defaults. The ultimate solution required inserting in the model code several UNIVAC peculiar (non-standard ANSI) OPEN statements.

C-7. ARGUMENT LIST CONFLICT. An error was corrected which involved an argument list conflict. The correction was made in three subroutines with assistance from Rand.

C-8. INCREASED SIZING. The selection of proper array sizes was found to be much more difficult than first anticipated (see paragraph C-3). This occurred despite excellent instructions for the selection process. The problem arises from the difficulty in predicting how many parts will be bought in requirements determination runs. Several arrays must be sized according to the maximum quantity of any part which will ever exist in a run. Arrays can, of course, be sized arbitrarily large, but the penalty is an unnecessarily large model.

C-9. SUPERFLUOUS REWIND. The existence of a superfluous REWIND statement caused a conflict with UNIVAC-peculiar file default attributes. The statement was unnecessary (according to Rand) and was deactivated.

C-10. DEVIATION IN TEST PROBLEM RESULTS. Initial runs of the Rand supplied test problem produced slight but unacceptable errors in two computed quantities. The problem was diagnosed by Rand as involving unintended truncation errors due to a single mixed-mode arithmetic statement. The offending statement was corrected and correct results for the test problem were obtained.

C-11. MODIFIED INPUT FORMATS. For the applications described in Chapter 3, it was necessary to define 12 aircraft deployment levels and 18 flying hour levels. Normal Dyna-METRIC input formats would have required input lines of 100 and 144 characters in length, respectively. Difficulty was encountered creating and editing these lines with the available UNIVAC text editor. An experienced computer user can readily see that the need for even more aircraft and flying hour levels would create difficulties with most text editors. The solution was to change the input format specification statements so that multiple lines could be entered. A good solution proved elusive, however, due to the manner in which Dyna-METRIC scans input lines. A crude fix was made to allow entering of the needed information for our application. A complete fix requires a moderate effort on Rand's part.

C-12. CORRECTION TO REPORT. An error was discovered in the technique used to compute stock purchases in two subroutines in the REPORT module. In certain circumstances the result was that the model effectively bought certain circumstances the result was that the model effectively bought negative stock. Rand diagnosed the problem and provided corrections for the relevant subroutines.

C-13. VARIANCE-TO-MEAN RATIO. Difficulty was encountered in attempting to define a variance-to-mean ratio different than the default value of 1 (corresponding to a Poisson distribution). The Dyna-METRIC version 4.3, used for this test, did not function properly for optional variance-to-mean ratios. This problem has reportedly been corrected in the new version 4.4, just released, but time did not permit testing the new release.

C-14. SUMMARY. The difficulties discussed above are considered reasonable, in view of the complexity and developmental nature of the model. With good documentation; well written, structured software; and good support from Rand; the problems were quickly solved. All test applications were successfully run and thoroughly checked, wherever possible, against other model results and manual calculations. No errors were indicated by checks against the final version used. The resource requirements of the final executable code, in decimal words, are:

PART	18,432
ECHO	48,128
PIPE	135,680
MOD	38,400
REPORT	78,360

APPENDIX D

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GLOSSARY

Aircraft Spares	Aircraft Spare Stockage Methodology Study (conducted by CAA for ODCSLOG; see reference 1)
ARLCAP	See "Overview"
ASL	authorized stockage list(s)
ATE	automated test equipment
AVIM	Aviation Intermediate Maintenance
AVUM	Aviation Unit Maintenance
AWP	awaiting parts
CAA	US Army Concepts Analysis Agency
CIRF	centralized intermediate repair facility (USAF term)
CONUS	continental United States
CPU	central processing unit (computer)
DA	Department of the Army
DARCOM	US Army Materiel Development and Readiness Command (now Army Materiel Command)
DT	delay time
DTIC	Defense Technical Information Center
Dyna-METRIC	Dynamic Multi-Echelon Technique for Recoverable Item Control (computer model)
FHP	flying hour program
FMC	fully mission capable
LOR	level of repair
LRU	line replaceable unit
MOS	military occupational specialty
NFMC	not fully mission capable
NMCS	not mission capable due to supply

NRTS	not reparable this station
NSN	national stock number
ODCSLOG	Office of the Deputy Chief of Staff for Logistics (Department of the Army)
OPTP	Overview/PARCOM Turnkey Project (parent study for the subject effort; performed for ODCSLOG)
Overview	Model developed by Synergy, Inc. for the Air Force to relate aircraft logistics resources to operational capabilities (computer model). Also known as Overview/ARLCAP (Army Logistics Capability) Model.
PARCOM	Parts Requirements and Cost Model (computer model)
PLL	prescribed load list(s)
QPA	quantity per application
RR	remove and replace (a repair policy for no on-site repair capability)
RRR	remove, repair, and replace (a repair policy including on-site repair)
SESAME	Selected Essential-Item Stockage for Availability Method (computer model) (see reference 6)
SRU	shop replaceable unit
USAF	US Air Force

TEST OF THE DYNA-METRIC AIRCRAFT READINESS AND SUSTAINABILITY ASSESSMENT MODEL (OPTP Dyna-METRIC)

STUDY
SUMMARY
CAA-TP-84-12

THE REASON FOR PERFORMING THIS WORK was to satisfy the concern resulting from the Aircraft Spare Stockage Methodology (Aircraft Spares) Study for a partial-substitution modeling capability. The Overview and PARCOM Models recommended by that study met all of the original objectives but did not allow for modeling partial substitution.

THE PRINCIPAL FINDINGS of the work reported herein are as follows:

(1) The Dyna-METRIC computer model can effectively represent a theater Army helicopter force in wartime for purposes of analyzing fleet sustainability and parts requirements.

(2) Dyna-METRIC results agreed well with those of the Overview and PARCOM Models in answering questions posed in the Aircraft Spares Study.

(3) Dyna-METRIC can represent full, no, and partial substitution of replacement parts.

(4) Requirements assessments under partial substitution cannot be performed directly with a single run. The feature could probably be added by the model developer without serious difficulty.

(5) An extended PARCOM, now available, includes the ability to represent partial substitution and eliminates the need for Overview. Although Dyna-METRIC can do most of what extended PARCOM does and has some additional valuable features, Dyna-METRIC is not recommended for aggregated theater level analysis (as in Aircraft Spares) because it is more difficult to use and interpret than PARCOM.

(6) Dyna-METRIC has unique features which are potentially valuable for higher resolution analyses than possible with PARCOM. Because testing was limited to a lower resolution problem not exercising these features, further evaluation of Dyna-METRIC is warranted.

THE MAIN ASSUMPTION was that parts fail according to flying hours only.

THE PRINCIPAL LIMITATIONS were:

(1) That treatments of partial substitution other than splitting the parts into substitutable and nonsubstitutable sets may not be addressable by Dyna-METRIC.

(2) That Dyna-METRIC was not fully tested for features relevant to expanded applications of possible interest to the Army but beyond the stated objectives of this work.

THE SCOPE OF THE WORK was to model an Army theater helicopter fleet in wartime in order to determine fleet sustainability and parts requirements based upon a postulated flying hour program. Maintenance resources were unconstrained in the analysis.

THE OBJECTIVES were to test the ability of Dyna-METRIC to represent: (1) theater level operations, (2) sparing to aircraft availability goals, and (3) partial substitution. Beyond these stated objectives, this effort also considered how Dyna-METRIC might improve Army spares analysis through (1) a detailed representation of the stochastic processes involved and (2) the modeling of more of the logistics system characteristics than were modeled in the Aircraft Spares Study.

THE BASIC APPROACH was:

(1) Duplicate the Aircraft Spares Study scenario and compare results with those from Overview and PARCOM.

(2) Evaluate partial-substitution capabilities.

(3) Examine sensitivity of results to selected key variables.

(4) Examine potential applications to more detailed studies.

THE SPONSOR was the Office of the Deputy Chief of Staff for Logistics, Department of the Army. This work was part of the Overview/PARCOM Turnkey Project (OPTP).

THIS WORK was conducted by Mr. Thomas A. Rose, Force Systems Directorate, US Army Concepts Analysis Agency.

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